Canada. Reconstruction, Advisory Committee on [Studies and factual reports].
No.10:- McFarlane, W.D.- The industrial utilization of agricultural products. 1942.

Canada. Reconstruction, Advisory Committee on. Studies and factual reports. No.10

[illegible]

[illegible]

[illegible] INDUSTRIAL UTILIZATION OF [illegible]

A Survey of Literature on the Industrial Utilization of Farm Products and Byproducts in Canada, Being Carried on by the Regional Research Laboratories of the United States Department of Agriculture.

By

[illegible] R. D. [illegible],
Macdonald College,
Ste. Anne de Bellevue,

[illegible]

This study was prepared for the use of the Advisory Committee on Reconstruction. The views expressed are those of the author and do not necessarily carry the approval of the Advisory Committee on Reconstruction or [illegible] Sub-Committees.

Advisory

COMMITTEE ON RECONSTRUCTION

THE INDUSTRIAL UTILIZATION OF AGRICULTURAL PRODUCTS

A Survey of Research on the Industrial Utilization of Farm Products of Interest to Canada, Being Carried on in the Regional Research Laboratories of the United States Department of Agriculture.

by

Professor W. D. McFarlane,
Macdonald College,
St. Anne de Bellevue,

1942.

ACKNOWLEDGMENTS

The number who have contributed information for inclusion in this report is too numerous to mention each by name. Grateful acknowledgments are due to the directors of the Regional Research Laboratories for their kindness in permitting the writer to visit all of the divisions of their respective laboratories and to discuss the work with members of the staff. The writer is particularly indebted to Dr. Lee T. Smith, of the Eastern Laboratory; Dr. G. E. Hilbert and Mr. S. T. Schicktanz of the Northern Laboratory and to Mr. A. L. Pitman, Dr. L. B. Howard and Dr. M. J. Blish of the Western Laboratory, for special assistance.

The writer also desires to express his indebtedness to Dr. Paul J. Kolachov and Mr. J. R. Steutz of Joseph E. Seagram & Sons Inc., Louisville, Kentucky; to Mr. W. R. Swint and Mr. J. F. Livingstone of E. I. DuPont de Nemours & Co., Wilmington, Delaware, and to Dr. George E. Holm of the Bureau of Dairy Industry, Washington, D.C., for much helpful information.

In the preparation of the report the writer received valuable suggestions from Dr. L. C. Marsh, Research Adviser to the Committee on Reconstruction.

CONTENTS

I. INTRODUCTION

Since 1939, the United States Department of Agriculture, through the Surplus Marketing Administration, has been charged with the responsibility for administering a wide variety of distribution programs which are collectively designed to increase consumption, to improve nutrition, and to offer a positive approach to the problem of surplus control and agricultural underemployment. There are three principal types:-

I. Those seeking to improve farm incomes by broadening markets among low-income groups and doing so to increase food and fibre consumption among these groups.

Programs of this type include the Food Stamp Plan; distribution of commodities for free school lunches; low-cost milk programs for school children and families, and distribution of foods to families directly where the stamp plan is not available.

II. Export Subsidies, and other techniques calculated to aid export markets.

III. Those seeking to induce a different utilization of agricultural commodities than would normally take place.

These include experimental programs to develop new uses for agricultural commodities and diversion to byproduct or secondary uses.

This report is concerned with the third type, that is, to promote the utilization of farm products and byproducts as industrial raw material.

There is some difference of opinion as to the relative emphasis to be placed on these different programs so as to deal effectively with surplus farm products. Naturally, agriculture's first responsibility to the nation is to see that farm production, both present and future, is sufficient to provide all people with abundans food - special programs to improve the diets of low-income groups are of primary importance. It is frequently stated that if the diet of all people is raised to a satisfactory level there will be no food surplus problem and therefore no justification for research on non-food uses for farm products. Although the food distribution program has been in operation in the United States for only three years and extends to only a small proportion of the population, it is evident that it will effect, or may be used to effect, great shifts in agricultural production so as to permit an increased consumption of the protective foods, mainly high priced animal products, and particularly milk. This in itself would be highly beneficial to agriculture. However, it is unlikely that the over-all consumption of farm products will be very materially affected. Many people consume an unbalanced diet but few actually lack sufficient food.

There is an element of danger in believing that the surplus problem in agriculture can be solved by raising the dietary level of all persons to the standards now advocated by nutrition authorities. Nutritional standards are still tentative, and subject to constant modification in the light of new discoveries. It is not improbable that the health of many adults would be improved by eating less food. Witness, for example, the improved health of the British people during a period of severe food rationing.

It is also assumed that the surplus production of the 1930's represents the maximum productivity of American soils whereas in this period we were actually deploring the loss of soil fertility due to erosion, etc., and it cannot be claimed that intensive scientific farming was being practiced on a wide scale, Post war production will probably be on a far higher level than has ever been achieved in the past. Improved farming methods are being adopted more rapidly under war conditions than would normally take place. Just before the outbreak of war, soil conservation programs were intensified and large

tracts of land in the United States were being made arable through irrigation. The effect of these measures on crop production is still to be realized. There will be a tremendous increase in the production of nitrogenous fertilizer after the war, as a result of new developments in the high-pressure synthesis of ammonia. Referring to this in an address to the American Chemical Society on September 7th, 1942, Charles M.A. Stein, vice president, E.I. du Pont de Namours & Co., said:

"The amount of fertilizer chemicals that this new capacity will be able to supply farmers will be so large that the basic trends of agriculture might be changed".

The year 1939 climaxed a decade of depression in world agriculture graught with problems of unprecedented magnitude involving fundamental changes in our economy and in our agricultural production. Surplus production assumed a permanent character due to the loss of foreign markets through the efforts towards economic self-sufficiency on the part of Nations; declining rate of population growth; improved methods of farming; changes in the food habits of the individual and, to a lesser degree, the replacement of natural products by those synthesized in the laboratory. Unless new uses could be found for the products of the land there appeared to be no prospect that so large a farm population as we had could earn a satisfactory living from agriculture.

We can envision the return of the same chaotic conditions within one or two years after the cessation of hostilities especially if we strive to create agricultural labor or attempt to keep farm workers employed on any particular economic level and at the same time neglect the search for new outlets for farm products. There is a definite limit to the amount which can be sold as food and future expansion must, to a large degree, depend on the extent to which farm products are used in the manufacture of the industrial commodities which the farmer is anxious to acquire.

The farm can be the source of industrial raw materials, and the possibilities for expanding agriculture in this direction are probably greater than those awaiting any other industry. In the past agricultural research has been directed to increasing production so that the farmer would have more to exchange for the comforts of life. In future, greater emphasis will be placed on utilization problems calling for a united effort by agriculture, industry, and science to find industrial raw materials which farmers can produce in substitution for their overproduction of food, thereby expanding rural life by opening up new markets and so achieve an equilibrium between farm and industrial incomes which will have a degree of permanency.

There is nothing new about these proposals. Industry has long been interested in the utilization of agricultural residues and wastes; the raw material of some of our oldest and largest industries is exclusively of agricultural origin. The depression period simply focused attention on the possibilities for expanding existing markets and creating new markets for farm products as industrial raw material. In a very short period research has developed a great variety of new commodities from products such as corn, soybeans, etc., but these enter into direct competition with the synthetic chemical industry, and it is evident that much research has still to be done before they can make a place for themselves in the competitive field. The substitution of one product for another represents progress only when the new product is cheaper, more abundant, or beneficial to more people than the one it displaces. Industry at present finds it cheaper to synthesize products from readily available elementary materials; coal, oil and petroleum, rather than to obtain the same products by breaking down highly complex natural materials so that there are, as yet, very few instances of the products of the land being able to compete with the products of the mines and oil wells as the cheapest source of industrial material.

Petroleum and agricultural crops are highly competitive. The importance of this fact is not yet clearly recognized by many of those interested in agriculture. If we consider North America as a unit petroleum and its byproducts can, for the present, be produced in much larger quantity than is

needed for power and heat - we have shown our ability to produce far more grain than we can use for food. The surpluses of both are available for other uses, particularly for the manufacture of organic chemicals. In the long run it is probably to the advantage of America that there be this competition, and that for her chemical needs these two sources of supply should be available. It is the function of the Government to see that no inadvisable or artificial barriers prevent the free working out of the competitive advantage of each. Under some circumstances, however, there are social, economic and political justifications for protecting an enterprise when it is in the National interests. For instance there is a fundamental difference between petroleum and agricultural products as raw material for the chemical industries, a difference which should be kept clearly in mind. With petroleum, we are drawing constantly upon our capital and our reserves, with agricultural products, we need use only the interest on our capital stock of land and climate, yet maintain our reserves.

Responsible authorities have repeatedly expressed the opinion that oil reserves are rapidly declining. Amongst the more recent statements to this effect is that by R.K.Davies, Vice-president, Standard Oil of California, addressing the American Petroleum Industry on November 6th, 1941:

> "Right now we are consuming, every 8 months, one-twentieth of the Nation's entire known oil reserves calculated at 20 billion barrels".

Further comments in this connection were made by Sir E.J. Russell, Director, Rothamstead Experimental Station, when discussing agricultural reconstruction before the Society of Chemical Industry in London, England, on July 10th 1942.

> "I have left to the last a problem which will grow in importance as years go by. Mankind is using up at a colossal rate the considerable but definitely limited stores of energy accumulated in past geological ages on this earth. Oil and coal are being consumed as rapidly as we can remove them from the earth, and every kind of ingenuity is displayed in devising new methods for more rapid extraction and destruction. Our descendants will have good cause to stigmatize this age as the most devastating the world has ever known and no doubt will regret that they can only curse us and nothing more. But there is still one source of energy available at present which is hardly stored for light or heat; the sun's radiant energy. The green plant has the power of fixing and storing the sun's energy. The process is not very efficient from the engineering standpoint, less than half of 1% of the energy received, being actually stored. But the amount is capable of being increased, and when the supply of energy becomes a problem this possibility will assume real importance".

The fact that Canada is a large importer of petroleum and its products is often overlooked when considering the relative merits of certain projects in this country as compared with the United States.

The greatest deterrent to the use of farm products industrially is the fact that there is no generally acceptable low-cost plan for local collection and concentration at convenient shipping points, nor has much progress been made in planning to use agricultural land for the sole purpose of producing industrial raw material. Agriculture, like any other industry can solve its problems through research. When capital is concentrated in industry the industrialist finds it profitable to spend large sums on research. In the United States the chemical industry spends 2-4 percent of its annual sales revenue on research, and one firm alone spends 7 million dollars annually. Only one-seventh of one percent of the total annual value of farm products is spent on actual agricultural research. The sum which Canada has been spending on agricultural research of this type must be infinitesimally small in relation to the importance of the industry and the complex and diversified nature of its problems.

To conduct research on new commercial processes requires a mass effort and much larger research appropriations. This type of research generally involves several phases; the idea, its development in the laboratory, pilot-plant experiments, semi-commercial scale experiments, and finally the development of a

full-scale commercial plant. Usually an estimate of the economic feasibility of the process cannot be made until pilot-plant work has been carried out and reliable information on costs can only be obtained by semi-commercial scale tests. Farmers, scattered in small units over a vast territory, cannot get together to originate and support such research - only the government and industry can do it for them.

In 1938, the United States by Act of Congress, established the Regional Research Laboratory of the Department of Agriculture to investigate the industrial utilization of the major crops, particularly those of which there are seasonal and annual surpluses. Here was the beginning of a gigantic effort to improve the economic position of the farmer through the medium of a government supported policy of chemical and engineering research.

Producers' cooperative and small plants looking for a sideline or an off-season activity, may be expected to supply much of the initial commercial development of processes conceived in the Regional Laboratory. It is believed that this kind of industrial growth would have the most direct beneficial effect on American agriculture. It would provide an opportunity for the employment of surplus agricultural labor; increase economic independence by diversifying markets and producing finished or semi-finished goods instead of raw materials and decrease waste in handling, storing, and transporting the products.

Small enterprises, however, as is well known, operate under some handicaps which place them at a considerable disadvantage as compared with great industrial concerns. One of these handicaps is that they rarely have access to the best of engineering counsel. As a result, many of the existing small processing plants have been built by guess and rule of thumb, and are unduly expensive to operate and maintain. The preparation of well considered equipment and plant designs can be a real contribution toward the successful operation of such enterprises. In the Regional Research Laboratories, therefore, emphasis is being placed, insofar as possible, on the search for principles, techniques and devices calculated to make a contribution to the success of decentralized rural industry.

APPENDIX

Recommendations as to the Application of this Type of Development to Canada

Increasing research; fundamental research in universities, pilot-plant research in new, Western branch of National Research Council. National Chemurgic Committee as advisory body; contacts with local branches of Boards of Trade, Chambers of Commerce, and Society of Technical Agriculturalists. Development of local industry. Economic questions involved.

The Regional Research Laboratories symbolize a development in agricultural research which cannot fail to influence the future of American agriculture. The late Dr. Henry G. Knight, who directed the affairs of the Regional Laboratories as Chief of the Bureau of Agricultural Chemistry and Engineering, told the writer he was firmly convinced that the future trend of chemical research would be towards the production of organic chemicals through the degredation of complex plant-products rather than through organic synthesis. He predicted a great expansion of chemical industries utilizing plant and animal products. The extent to which Canada participates in those developments will depend upon the importance attached to the position of agriculture in the national economy. In planning for the post-war era particular emphasis should be placed on scientific research to utilize more effectively our agricultural resources, which constitute real wealth only when developed through the constructive exertion of capital, labor and intelligent management.

If it is agreed that research on the utilization of farm products should be extended after the war, the practical policy is to begin its organization now within the framework of existing institutions. It has already been pointed out that two clearly-defined types of research are involved; fundamental research and semi-commercial or pilot-plant investigations. Each of these requires appropriate facilities.

Fundamental Research

The university laboratory is the logical place in which to conduct fundamental studies on the composition and properties of the complex primary constituents of animal and vegetable matter. Fundamental research of this nature, with the objective of developing economic processes for manufacturing industrial commodities from agricultural materials, could be encouraged in the universities by extending the research scholarship policy of the National Research Council. The universities would have an added responsibility to train chemical-engineers with a background of experience in agriculture and industry.

The experience of the Regional Research Laboratories would indicate that the interests of agriculture can best be served by recommending the establishment of a branch of the National Research Council, limited to research on the industrial utilization of crops and with special facilities for pilot-plant investigations. Some may doubt the wisdom of government agencies attempting to develop laboratory findings into practical commercial processes, believing instead that the government should assist private enterprise in such developments or leave it entirely to private capital. However, applied research on commercial processes is now the main activity of the National Research Council, This policy, already adopted by the government, would appear to be particularly applicable to the agricultural industry.

This new branch of the National Research Council laboratories should be located in the area best suited to industrialized agriculture and to the growing of crops for the sole purpose of producing industrial raw material. Obviously, the Prairie Provinces are ideally suited to this type of agriculture and hence the logical choice of location is Winnipeg, since it is the outlet for most of the farm products leaving the west and provides for contacts with both agriculture and industry.

The Division of Biology and Agriculture of the National Research Council in Ottawa, and the Ontario Research Foundation in Toronto could provide a comparable research service in the development of agricultural industries in the central and eastern provinces. The excellent co-operation which now prevails between the Department of Agriculture and the National Research Council augurs well for the success of some such scheme as this.

Liaison with Industry

The fullest co-operation of industry could be procured through the National Chemurgic Committee acting in an advisory capacity and assisting in formulating plans for the work of the laboratories. This committee is comprised of agriculturalists, industrialists and research chemists and has at its disposal the machinery through which to enlist the interest and co-operation of local Boards of Trade, Chambers of Commerce, and branches of the Canadian Society of Technical Agriculturalists. Through these organizations problems could be considered from the national standpoint; information disseminated regarding the technological aspects of the utilization of various farm products and recommendations received for establishing local industries.

Some thought should be given to these proposals now to decide how they can be incorporated in a post-war agricultural program. As a contribution to reconstruction planning it would not be premature to begin blue-printing the project, including a detailed plan of chemical-engineering research most likely to contribute to the rehabilitation of agriculture.

Rural Industries

It is believed that research to develop rural industry would contribute most to the solution of post-war problems. Referring to this in an address to the Society for the Promotion of Engineering Education on June 26th, 1942, Professor Arthur W. Hixson of Columbia University, said:

"There will undoubtedly be a greater trend toward decentralization of industries in the form of smaller manufacturing units. I believe that individual initiative and private enterprise will be encouraged and that the economic hazards of starting and operating small business enterprises will be largely removed by new stabilizing agencies of semi-governmental nature, much as industrial loan corporations similar to the present Home Owners Loan Corporation and the Agricultural Loan Corporation."

This kind of industrial development would have the most direct beneficial effect on agriculture. It would provide an opportunity for the employment of surplus agricultural labor and so encourage young men to stay in rural areas; increase economic independence by diversifying markets and producing finished or semi-finished goods instead of raw material; and decrease waste in handling, storing and transporting the products. The success of decentralized rural industry will depend to a large extent on the designing of typical plants adapted to economical construction and operation, and improved equipment for processing agricultural materials and their by-products.

A review of the activities of the Regional Research Laboratories in the light of Canadian conditions suggests the following projects for first consideration in the promotion of rural industries:

(1) Manufacture of Building materials as part of a post-war scheme for improving rural housing. Specifications would have to be worked out for small-scale manufacture of wallboard, structural insulation and other building materials. In this connection consideration should be given to the small-scale manufacture of low cost plastic materials which can be made from some abundant raw material, such plastics to be used as decorative wall coverings, as fittings and sundry and for other building purposes. An important lead has been given by the Iowa Engineering Experiment Station. The furfural to be used in the manufacture of these plastics could be produced locally from waste hemi-cellulose materials. Plastics for specialty purposes, as a "handicraft" industry is attracting considerable interest.

(2) Pulping operations as a community co-operative enterprise
The use of a special fiber, seed-flax straw, to produce a special result in paper making i.e. cigarette paper manufacture, not obtainable with wood-fiber, suggest a logical use of other cereal-straw fibers for cellulose purposes, namely for specialty papers. The problem of collecting and segregating agricultural wastes economically must first be solved.

(3) Processing oil-seeds as a rural industry.
Instead of transporting oil-seeds long distances to large extraction plants, located in cities, and shipping the byproduct meal back to the farms it might be more logical to process the seeds in areas where they are grown and where the byproduct feed is consumed, and ship the oil to centralized refining plants. This would require a small-scale extraction unit using a stabilized non-inflammable solvent and equipped to produce the meal in an edible condition.

(4) Small-scale grain alcohol plants community operated in competition with molasses derived alcohol.
Careful consideration should be given to the proposals originating in the research laboratories of Joseph E. Seagram and Sons Inc., for utilizing farm products in the production of ethyl alcohol, farm motor-fuel. Our future needs for industrial alcohol will undoubtedly increase with our chemical progress.

(5) Whey drying at cheese factories and small casein plants.
Special attention should be given to the production of lactic acid which is a remarkable chemical intermediate and can be transformed into a number of valuable organic chemicals and resins. Whey is the most economical source of lactic acid but transportation difficulties and the problem of providing for the year-round operation of an industrial plant can only be solved by drying the whey in economical small-scale drying units. Lactic acid and butylene-glycol are good examples of the possibilities of utilizing agricultural materials for the production of war essentials and so producing chemicals which will later find extensive peace-time uses.

(6) Dehydrated foods as a permanent industry after the war.
The rapid advances in taking the water out of foods may be leading to a new era in the history of food. Dehydrated foods are certain to hold their importance at least during the reconstruction years. Dehydration offers a practical means of utilizing local and seasonal peaks of production; it is the most effective way to conserve food supplies and move them cheaply and easily wherever they are needed; and through the new developments in precooking, it means time saved in the kitchen.
Small farm dehydrators of a size which represents a food compromise between cost of production and usable capacity, should be designed to enable the farmer to dry his own crop.

Many other suggestions for inclusion in a research program have already been reviewed in the National Chemurgic Committee's report, "Survey of Canadian Research on the Utilization of Farm Products" (chapter on "Synopsis of Commodity Reports"). New developments since the survey was prepared, which may increase in importance with a long war and may lead to the establishment of new industries are the cultivation and processing of:

(1) The dandelion, "taraxicum kok-sagyz", as a source of rubber latex. Experimental work, done in Canada and in the United States this summer, indicates that this rubber-bearing dandelion has possibilities for developing a domestic rubber supply.

(2) Hemp, as a source of fiber adapted to the manufacture of cordage, sacking, convas, etc., in substitution for Bengal jute. It is also valuable for its resin; for the oil (30%) contained in the seed to be used for soft-soap and paint; and for the seed itself.

(3) Milkweed, as a source of "floss-fiber" to take the place of Kapok imported from the East Indies. In the present emergency Kapok is on the list of urgently needed raw materials because of its use in life preservers, life jackets, etc. As milkweed floss is only one of seven other byproducts obtained from the milkweed plant and as a milkweed-gin has been perfected which separates the floss from the seed in an economical manner, the crop has merits to warrant its production after the war.

The war has provided an exceptional opportunity for agriculture to demonstrate to industry that it can produce raw materials essential to the prosecution of the war, and to replace many commodities in everyday life which were formerly imported and which are no longer available.

Anyone who has studied the question will realize that valuable chemical research could be conducted in many fields with practical benefits to agriculture if it were indicated that the economic questions could be clarified. The greatest deterrent to the use of farm products industrially is the high cost of the raw material. Wheat, for example, is the least desirable farm product for industrial purposes since its economic value is determined by its value as a human foodstuff, yet it could be the basis of a coordinated industry making full use of the germ, gluten, starch and structural carbohydrates. A "two-price" system has been suggested for food products with industrial possibilities. This would be feasible, particularly if price control were to be continued in some form after the war; the price of the commodity as industrial raw material could then be related to the price of the commodity as food in some reasonable ratio.

Since we have a relatively small consuming population, industrial enterprises such as we envision must be built up largely on the export of new commodities which have been discovered in our own laboratories and are protected by patents. A perusal of the long list of patents issued each year serves to illustrate the dominant position which American enterprise has in our food, pharmaceutical and general chemical industries. Surely research of the nature outlined in this report is particularly vital to Canadian development, and surely we should see to it that we make our own contribution and obtain our own fair share of patents after the war.

It is not unimportant to add, finally, a word about our resources in trained personnel. We must ensure against the return of conditions as they prevailed before the war when chemists with advanced degrees were competing for positions in the government service paying day-labor wages, while little or no research of this nature was being done by Canadian industries. In the United States a great deal was being done by commercial concerns, many of whom operated large subsidies in Canada, but their research was done across the line, and quite often done by Canadians who were denied an opportunity to apply their research training in their won country. Men with this training will be needed for post-war reconstruction in Canada if this is to be imaginative, and far-sighted.

II. THE BROAD SCHEME OF THE REGIONAL LABORATORIES

The establishment of the four research laboratories, provided for in the United States Agricultural Adjustment Act of 1938, was preceded by a survey to determine the location of each of the four laboratories within the major producing areas of the country; designate the farm commodities which would receive initial research attention; define the scope of the new investigations and coordinate with the research already in progress. The report of this survey was published in 1939 as Senate Document No. 65[x] of the 76th Congress.

The location of the laboratories and assignment of the commodities which were to have first attention by research was designated as follows:-

Eastern Laboratory - Chestnut Hill, Philadelphia, Pennsylvania.
(Potatoes, milk products, tobacco, apples and vegetables).

Northern Laboratory - Peoria, Illinois.
(Corn, wheat, agricultural waste products).

Western Laboratory - Albany, San Francisco, California.
(Fruit, vegetables, potatoes, wheat, and alfalfa).

Southern Laboratory - New Orleans, Louisiana.
(Cotton, Sweet potatoes, and peanuts).

It is expected that the laboratories will in due time give attention to many more classes of commodities.

Construction of the buildings and the installation of equipment was completed in 1940 at a cost of $1,500,000 for each laboratory. The buildings are practically identical in design and are U shaped structures of three stories (see photographs[xx]). The base of the U, which is the front of the building is 211 feet long and comprises the administrative offices, the library and conference rooms. The wings of the U are 258 feet long. One of these wings is completely occupied by research laboratories equipped for work in chemistry, physics, and biology. The other wing contains several laboratories and a pilot-plant. The function of the pilot-plant is to test, on a scale large enough to determine its practicability for commercialization, any new use developed by the laboratory staff. In addition to the U shaped building, there is a service building containing the heating, air conditioning, and steam plants.

The laboratories were completed at different dates so that some of them have been in operation for two years and others just over one year. Each laboratory has an annual appropriation of $1,000,000 providing for an administrative staff comprised of a director and his technical assistant, a business manager and a mechanical superintendent; and a technical staff of 200-250 trained scientists organized into seven or eight research divisions, each with a director and a staff of 25-30 chemists, engineers, and chemical engineers. In choosing the research staff, preference was given to men with previous industrial experience.

The plans for the work of the laboratory are formulated and guided largely by an advisory committee of outstanding scientists from Universities and certain federal and state research institutions. Frequent consultations are held with the directors of the State Experimental Stations to review the research projects and to define their respective fields of activity.

The fullest cooperation is invited from industry and this is achieved through an industrial relations committee representing banking, railroads, chemical industry, etc: some forty to sixty organizations are represented at the Annual Meeting of each laboratory. The interest shown by industry is indicated by the fact that some large chemical concerns have already delegated members of their staffs to maintain contact with the work of these laboratories.

x Obtainable from the U.S. Govt. Printing Office, Washington, D.C. - Price 50 cents.

xx Photographs on request to the Department of Reconstruction.

The laboratories do not do any control analytical work for outside concerns nor do they provide a consulting service but industry is kept informed of new research developments. This information is usually given out at a conference on the particular subject at which the interested parties are represented.

Cooperative projects can be arranged between industrial concerns and the regional laboratory; the basis of the agreement being a "Memorandum of Understanding" which stipulates what each party is to contribute. When the regional laboratory can provide special facilities, such as pilot-plant equipment, arrangements may be made whereby the firm will supply one of its own specially qualified men to do the work in the regional laboratory and pay his salary.

The present practice with respect to patenting research findings is to take out a Public Service Patent which is assigned to the Secretary of Agriculture who can license the patent with some restriction or regulation. This simply prevents someone else patenting the process. Consideration is being given to the question of providing an exclusive license to industries contributing funds towards the research. It is also believed that at some future time provision will be made by Act of Congress whereby royalty rights may be collected.

One of the most important features of the Regional Laboratories is the establishment, in each, of an Engineering and Development Division the function of which is to devise new or improved equipment for processing agricultural materials and their byproducts and to design typical plants adapted to economical construction and operation in such utilization processes. The successful development of a new process in industry invariably involves at some point the research technique known as engineering design. Even if the new development requires no more than the rearrangement of existing equipment or the assembly of a group of standard grinders, dryers, tanks, and pumps, the element of invention is always present to some degree. Industrial experience teaches that many a process which appears in the laboratory to be simple and inexpensive requires the inventive talent of the plant or equipment designer to make it either operative on economical. In fact, numerous examples might be cited of processes whose commercial adoption is waiting for the ingenuity which will devise efficient large-scale equipment.

The writer recently visited three of the four regional laboratories and was given every opportunity to see all that was going on. The research activities of these three laboratories is reviewed below. The Southern Laboratory was not visited because of lack of time, and at any rate, the work in this laboratory is of secondary interest since the commodities being investigated do not grow in Canada. Before the regional research laboratories were established, research on industrial uses for farm products was confined largely to the chemical laboratories of the Department of Agriculture in Washington. A considerable amount of this research is still being done in these laboratories but, it will be transferred to the eastern research laboratories as time permits. The Washington laboratories were also visited and a report of the work in progress is included in the following discussion of the research activities of the eastern research laboratories.

III. THE EASTERN LABORATORY

The following is a summary of the research programmes of the various divisions in this laboratory:-

Analytical and Physical Chemistry Division:-

General routine chemical and physical analyses. X-Ray, spectrographic, and other specialized physical, chemical and physico-chemical testing and investigations of commodities assigned to the Laboratory and their products and derivatives. Isolation and identification of tobacco constituents, relation between chemical composition and quality of tobacco.

Biochemical Division:-

Apple utilization investigations, including juice, concentrate, pectin, wax and other apple products and constituents. Utilization investigations on vegetables, vegetable products and consituents. Chemical studies on tobacco, isolation of nicotine, preparation of nicotine derivatives for insecticides, nicotine as a source of nicotinic acid.

Carbohydrate Division:-

Chemical studies on lactose, including preparation of derivatives and their utilization in production of new and useful products. White potato utilization investigation, preparation of white potato starch, modification by physical and chemical treatment; application of its products and derivatives to new and improved methods of utilization.

Chemical Engineering and Development Division.

Pilot-plant studies of laboratory processes and products, including design, construction, and operation of pilot-plant equipment for manufacture of white potato starch, isolation of nicotine from tobacco, and manufacturing of plastics. Equipment and large-scale apparatus design. Engineering consulting service to the laboratory.

Hides, Tanning Materials and Leather Division.

Experimental and commercial testing of liquors and extracts from tanniferous plants and agricultural wastes in the tanning of leather to ascertain new sources of vegetable tanning materials. Studies on the chemistry of the tannings. Methods of curing hides and skins, including development of new methods. Experimental studies on treating, tanning and finishing of leather.

Oils and Fats Division.

Studies of the chemistry, structure and properties of the animal fat glycerides, their components and derivatives. Studies on development of new products, including surface active agents, from animal fats and oils. Quality and stability studies of animal fats and oils, including lard, to produce new and improved methods of production, processing and preservation.

Protein Division.

Chemical studies relating to development of casein and other milk proteins for commercial use, including utilization of casein for plastics and in manufacture of synthetic fibers. Investigations of the basic composition and properties of proteins.

It will be noted that this programme includes a considerable amount of more or less fundamental research. It was intended that some investigations of this nature should be carried on in all of the regional laboratories because the development of economic processes for manufacturing industrial commodities from agricultural materials will depend largely on a better understanding of the composition and properties of the complex primary constituents of animal and vegetable matter, i.e., proteins, fats and carbohydrates. When the United States entered the war these research plans were modified, fundamental research gave way to applied research, special emphasis being placed on those projects concerned with the production of materials of strategic importance.

Research in Progress*: (i) Utilization of Milk Byproducts.

The great economic loss in the byproducts, skim milk and whey, is through inefficient utilization rather than by actual wastage. The great bulk of the skim milk is fed on the farms and is only potentially available for manufacturing purposes. It is estimated that the total skim milk, buttermilk and whey potentially available in Canada is eight to nine billion pounds, and that only some 400 million pounds is utilized in industry. The industrial utilization of milk byproducts is of limited practical interest to Canada at the present time, since there is a great demand for skim-milk powder which cannot be met by present production, e.g., to produce "Canada approved - White Flour" which contains 4% of dry milk solids. However, we should be keeping in close contact with every new development in this field so as to be prepared for the day when we have surpluses of these products again.

(A) Casein:

The most important develpment in recent years concerns the transformation of casein into a fiber of textile utility commercially known as "Aralac". The main steps in the process consist of forcing a solution of casein, of the correct viscosity and "stringiness", through spinnerettes into an acid precipitating bath and collecting the filaments on a reel or bobbin. After-treatment of the fibre consists of a relatively long immersion of the fiber in a formaldehyde bath, cutting it to the desired staple length and drying it under controlled humidity and temperature conditions.

Casein fibre has been produced commercially in several European countries since 1938 - Italy produced 30 million pounds of casein fibre "Lanital" in 1940. This product was only of fair quality and was not good enough for American users. A greatly improved product - "Aralac" was produced by Dr. F.C. Atwood, Atlantic Research Associates Inc., Newtonville, Mass., and was readily accepted by the textile industry. A factory for producing this fibre was built by the National Dairy Products at Taftville, Conn., and is producing close to one million pounds per month. The public is now being offered a new class of cotton and rayon fabrics containing up to 40% of "Aralac". It is the lowest cost protein fibre available and is said to give cotton and rayon goods the warmth, resiliency and drape of a woollen garment. The fibre has also many unique properties which add materially to the versatility of the textile industry without supplanting or interfering with the use of any present textile fibres. The textile industry would take 30-40 million pounds per month if it was available but further expansion of the industry is not likely to be realized for some time as casein production is expected to be restricted.

There are many problems still to be solved concerning the production of the fibre and improving its properties, some of which are being investigated in the Eastern Laboratory, e.g.

(1) The recovery of casein from skim milk to improve yield and qualtiy. Some of the newer protein precipitants, including various sulfonic acids, are being investigated. Cellulose sulfate shows particular promise from the standpoint of efficiency and low cost.

* In what follows it is understood that related investigations at the Bureau of Chemistry and Engineering, U.S. Department of Agriculture, are included. Technical data will be referred to only in so far as is necessary to illustrate the nature of the research work.

(2) The problem of spinning casein fibre is more difficult, or at least, different from spinning cellulose filaments to produce rayon. Increased strength in the fibre is desired so as to withstand reasonable carding, combing, and spinning operation without help from other fibres. An experimental spinning machine has been installed and is being used to study the problem from various aspects e.g. (a) modifying the structure of casein by chemical treatment with acetic ahydride, ketone, etc., or by introducing amino acids such as cystine, threonine and serine; (b) changing the composition of the solution used to dehydrate the filament in the precipitating bath by including aluminum compounds etc., and (c) controlling the conditions for after-treatment and drying of the fibre.

These researches may contribute to the solution of problems involved in the production of casein plastics in general such as shortening the time of manufacture and the production of a less brittle material which can be molded. It is unfortunately true that less is known about protein formaldehyde plastics than any of the other kinds of plastics.

(B) Whey Products - Lactose and Lactic Acid Production and Utilization.

Unlike skim milk solids the utilzation of whey solids in human food has not received much attention, the greater part is fed to animals but considerable quantities are actually wasted. Milk is the only source of lactose and whey contains 7% of solids of which 70% is lactose and 14% is protein. The huge potential resources of lactose available in the form of whey has attracted industrial interest because lactose can be rapidly and economically fermented to lactic acid, which, by virtue of its two active functional groups and chemical nature, is a remarkable chemical intermediate which can be transformed into a number of valuable organic chemicals and resins.

It has been estimated that there is available, in the United States, over 3 million short tons of whey (exclusive of the whey now being dried and sold as such) which is equivalent to 137,000 short tons of lactose. This is distributed amongst about 5,000 cheese or casein factories having outputs varying from a few thousand to over 50,000 pounds of whey per day. Very little whey is therefore available in large volume at any one place, but there are many centres of production where whey could be concentrated at one point without prohibitive expense. Furthermore the wide seasonal variation places definite limits on the type of manufacturing process which can be operated profitably. The only solution to the transportation difficulties and the problem of providing for the year-round operation of an industrial plant is to dry the whey. This would require an economical small scale unit for drying whey at cheese factories and small casein plants.

The Bureau of Dairy Industry, Washington, has developed an efficient small scale spray-drier for drying whey. A drum drier would be less expensive but whey cannot be drum dried, even when concentrated to 40% solids, because of interference due to crystallization of lactose. The whey powder is suspended in 95% ethyl alcohol in which the lactose is soluble and the protein insoluble. The protein is separated using a centrifugal separator. The proportion of alcohol to whey powder is such as to give a super saturated solution from which the lactose is readily crystallized by seeding with a small amount of crystalline lactose.

The alcohol is completely recovered in a rectifying still, thus making the process relatively inexpensive. Riboflavin (vitamin B_2) of which whey is a relatively rich source, is absorbed on the lactose crystals. One recrystalization of the lactose gives a pure product and also a vitamin-rich concentrate. There is an excellent market for the riboflavin concentrate to incorporate in poultry feeds, especially since skim milk powder has become so scarce. Uses for the protein residue are being sought and efforts are being made to produce a low-ash undenatured whey protein.

The most obvious use of lactose is through fermentation to lactic acid which can be done economically and in high yield with relatively little and simple equipment. Lactic acid can be readily converted into (a) colorless, transparent plastics such as acrylic resins suitable for use in metal finished, protective coatings and impregnation of fibrous materials; (b) synthetic resins and rubbers including Buna N and Perbunan types; and (c) alkyd resins suitable for use as plasticizers and lacquers.

As a result of the research and development work at the Eastern Laboratory it is estimated that the potential market for lactic acid is now vastly greater than the previous normal market of about 5 million pounds. The more important outlets are in leather finishing, plastics, synthetic rubber, alkyd resins, coating and impregnation of fibrous materials and foods.

At the present time lactic acid can replace a wide variety of strategic materials, Its importance in this connection is illustrated by the following summary:-

Replacement of Strategic Materials With Lactic Acid

Lactic acid possesses two functional groups. It is possible therefore, to form readily dimetallic salts, esters, ethers, and numberous compounds of these derivatives. Many of these materials have utility in the manufacture of munitions and synthetic rubber or as replacements for strategic organic solvents, plasticizers, lacquers, plastics, varnishes, impregnating compounds and viscosity index stabilizers for airplane and automobile lubricants.

1. Alkyd Resins: Many of the chemicals (phthalic anhydride, glycerol, glycol, etc.) used in making the important alkyd resins cannot be produced at present in quantities sufficient to meet the wartime demand, Lactic acid can be used to replace both the acids and the glycols used to make alkyd resins. Perhaps in the beginning it would be better to replace only small percentages of the standard materials, but probably much larger amounts could be used as the art develops.

2. Plasticizers: The shortage in the most widely used plasticizers, alkyd phthalates, phenyl and cresyl phosphates, etc., can be largely alleviated by the substitution of lactic esters. Since lactic acid can be had for as little as approximately 10 cents per pound, lactic esters should be actually lower in cost than most of the present plasticizers.

3. Solvents: Shortages exist among solvents, toluene, alkyd acetates, acetone, methyl alcohol, etc. Probably some of these could be replaced with some of the lower boiling lactic esters. Lactic esters could be used to an increased degree also for the replacement of lubricants, modifiers, etc.

4. Anti-Freezes: Present production of all the components of the common anti-freezes, is insufficient. Hydrogenation of lactic esters yields propylene glycol in good yields. This chemical should alleviate the situation as far as supplies of methanol, ethanol, glycol, and isopropyl alcohol are concerned.

5. Humectants: Sodium lactate, glycerol monolactate, glycerol dilactate, glycol monoplactate, and propylene monolactate can replace humectants such as glycerol and sorbitol in tobacco and cellophane.

6. Explosives: Propylene glycol, which is obtained by reduction of lactic esters, could be used to make propylene glycol nitrate, of interest as an explosive.

7. Acrylic Resins: Lactic esters can be converted easily and at low cost into acrylic esters, the intermediate used in making some of the important acrylic resins. Use of lactic acid for this purpose would release ethylene, hydrogen cyanide, mineral acids, and chlorine for other purposes. For example, the ethylene could be used to make styrene or ethanol. By using the acrylic resins to make safety glass, vinyl resins could be used for other purposes. Acrylic resins have many uses, one of which is to improve the temperature viscosity characteristics of lubricating oils.

8. Foods and Beverages: Lactic acid can be used for many such uses to replace citric acid, and possibly tartaric acid.

9. Synthetic Rubber: Buna N, one of the most important types of synthetic rubber, is made of butadiene and acrylonitrile. It is possible to prepare acrylonitrile from lactic acid at a reasonable cost, and in this manner relieve ethylene and hydrogen cyanide of some part of their burden. Polymerization of butadiene in the presence of acrylic esters also yields synthetic rubbers.

10. Waxes: It is difficult or impossible to obtain some of the waxes previously imported, Esters and amides of lactic acid made from alcohols, acids, and amines of high molecular weight such as stearic acid, lauryl alcohol, stearyl amine, etc., should be interesting as wax substitues.

11. Vitamins: Beta-alanine, which is used in the synthesis of pantothanic acid (a recently discovered important vitamin) can be made by adding ammonia to acrylic acid. Cyanopropionic acid is used at present to make beta-alanine - hence preparing beta-alanine from acrylic acid (from lactic acid) would save acetic acid, chlorine, and sodium cyanide for other purposes.

12. New Resins by Interpolymerization: Many and varied types of resins and rubber-like plastics can be made by polymerizing acrylic esters in the presence of other intermediates, such as acrylonitrile, styrene, vinyl chloride, vinyl acetate, vinylidene chloride, chloroacrylic esters, cyclopentadiene and indene.

A further development of particular significance at the present time when limited supplies of tin are available is the preparation of an excellent lacquer, suitable as a coating on iron food containers, by combining dehydrated lactic acid with a vegetable oil to form a resin. The dehydrated lactic acid is prepared by a process developed in the laboratories of the Bureau of Dairy Industry, in which the free and combined water is removed from the aqueous lactic acid by distillation with a high boiling liquid such as xylene, the water withdrawing liquid being continuously returned to the still after the water has separated out. This product in itself will probably be found to have important uses. For use on food containers the resin is dissolved in acetone or benzene and non-toxic driers added to form a baking lacquer. Application for a public service patent covering the process of making the lacquer has been made.

A process for fermenting the lactose in whey with organisms of the "Torula" type to produce ethyl alcohol of unique quality has been perfected in the same laboratories. The economic practicability of the process will depend upon local operating conditions. Over 12 million gallons per annum of sulfite liquor are processed for ethyl alcohol in the United States. The sulfite liquors do not average over 3% of fermentable sugar, whereas, whey never contains less than 4.5%. In addition the slops remaining after the fermentation of whey would contain enough riboflavin to be of particular value for stock feed. While the cost of whey assembled for fermentation is uncertain (said to be about 15 cents per 100 lbs.) it is probable that it would be a lower cost raw material than molasses. Its disadvantage is in the higher steam cost, which would be about three times that of distilling a molasses mash.

(ii) Utilization of Animal Fats:

At the present time, special attention is being given to the production of strategic materials from fatty acids and their derivatives. Fatty acids form excellent raw material for the preparation of new and unusual products and for the production of soaps, detergents, wetting agents and intermediates for plastics, artificial fibers and rubberlike materials.

With the exception of milk fat, no fat or oil is produced in any quantity in North America which contains sufficient short-chain fatty acids (particularly lauric acid), for the preparation of free-lathering soaps, powders and creams. Since the supply of cocoanut and palm-kernel oils has been largely cut off, the only possibility of producing lauric acid is by degredation of the longer-chain fatty acids which are the major components of domestic animal and vegetable fats and oils. This problem is being investigated at the Eastern Laboratory and also the following:-

(1) The chemical modification, excepting polymerization, of the unsaturated fatty acids and their derivatives. Including the action of oxidizing agents, catalytic reactions, pyrolysis, amination, phosphorylation and the formation of estolides and lactones.

(2) Utilization of animal fats for surface-active agents.

(3) Utilization of phenolated stearic acid, particularly as an additive agent to lubricants, as part of a general study of the preparation of special, extreme pressure, lubricants from animal waste fats.

(4) Quantitative recovery of glycerol in the hydrolysis of fats and the preparation of colorless fatty acids of special purity.

(5) Mechanism of detergent properties of soluble soaps.

(6) Stabilization of fats and oils against rancidity by the use of antioxidants. Fatty acid esters of ascorbic acid (Vitamin C) and d-isoascorbic acid are being prepared and their antioxidant potency determined. The stabilization of domestic lard by incorporating hydrogenated lard flakes is also being studied.

Fundamental investigations on the chemistry and technology of the production, processing, preservation and uses of animal fats, along the lines cited above, may tend to increase the monetary value of animal fats which had been on the decline for several years before the war.

(iii) Tobacco Byproducts:

As a result of seasonal condition, large portions of the tobacco crop are produced that are less desirable or unfit for normal leaf tobacco purposes. Each year there is a low grade portion of every crop, that should be used if practicable for byproducts instead of being offered in competition in the regular leaf tobacco channels. It is estimated that 76,000 tons of tobacco are available yearly in the United States for the manufacture of byproducts such as nicotine, malic acid, citric acid and oxalic acid. From this quantity of toabacco it is possible to obtain 8 million pounds of malic acid, 3 million pounds of citric acid and 3 million pounds of oxalic acid.

Looking to the development of new and extended uses of tobacco, the following research program is underway at the Eastern Laboratory:-

(1) Studies on the more extended use of nicotine and various nicotine compounds in insecticides and veterinary remedies including improvement in the efficiency of nicotine and its compounds as insecticides by means of carriers and activators.

(2) Production of nicotinic acid from nicotine. About one-quarter million pounds per annum of nicotinic acid are required for the fortification of bread and for use in medicinals. A process has been developed but so far it has proven too expensive to compete with the production of nicotinic acid from coal-tar quinoline.

(3) Studies on the recovery of organic acids, particularly citric and malic acids, and other constituents from green tobacco and from the cured leaf.

(4) Study of the practicability of increasing nicotine recovery from tobacco by means of oxidizing agents and the development of factory methods for extracting nicotine and other constituents from green, uncured tobacco.

(iv) Apple Byproducts:

Because of the increase in competition between apples and other table fruits as foods and the exceedingly large surpluses which very frequently occur, it is essential that new uses, preferably non-food, be developed if normal production from the present plantings is to be continued. Pectin is one of the most important and prospectively useful constituents of the pulp and peel. New or improved methods for its extraction are being developed, and the influence of the various methods on the properties of the resulting product are being studied. A very detailed investigation is being made of the properties of pectin and particularly of its derivatives. Since part of this investigation is being carried on in the Western Laboratory, it will be discussed in more detail when reviewing the work in that laboratory.

The Eastern Laboratory has recently developed a bland, very sweet syrup from apple juice. It is light amber in color and possesses no distinctive flavor, even apple flavor. With 75 percent solids, the syrup contains on an average, 40 percent levulose, 13 percent dextrose, 14 percent sucrose, and 8 percent non-sugar solids. Although certain details of the process need further study, it is believed that the main features are established and that it is commercially feasible. They think this product should be called to the immediate attention of apple processors and other interested parties for the following reasons:

1. There is an urgent need for every possible source of sugar, and the apple is one of them.

2. Preliminary findings indicate that apple syrup would be accepted by a number of industries and probably by home consumers.

3. The process is simple, and could be undertaken by any group possessing the required equipment.

4. Plans for manufacturing the syrup should be made as far in advance of the season as possible to get the necessary equipment installed in time to handle the crop in season.

The apple has never been considered seriously as an industrial source of sugar in spite of the fact that its juice contains about 11 percent sugar. A reason for this is found in the facts that rather low-priced apples are required to compete with the usual sources of sugar and that only a syrup and not a dry sugar can be obtained from apples. Today all possible domestic sources of sugar products are being re-examined because of the shortage of cane and beet sugars. In cane and beet juices, the predominant sugar is sucrose, with traces of dextrose

and levulose. In apple juice, levulose represents 58 to 75 percent of the total sugars, the dextrose and sucrose are present in about equal amounts. This combination of sugars is very desirable for a sugar syrup on account of the great sweetening power of levulose, which makes this syrup 20 to 30 percent sweeter than a cane syrup of equal sugar content. It is worthless, however, as a source of crystalline sugar owing to the difficulty of crystallizing levulose.

According to United States statistics, in a normal year there should be enough unmarketable but sound apples throughout the country to produce one or two million gallons of this type of syrup, exclusive of the regular apple juice concentrate. In 1942 there may be a greater supply, owing to lack of export markets, lack of cans for juice and other apple products, and an expected large crop. The real limitation, however, is believed to be the shortage of vacuum evaporators. If new evaporators cannot be obtained, it is suggested that evaporators used for other products, such as milk, fruit juices, and tomatoes be used for apple syrup. Because of the possible lack of evaporators, however, it is useless to try to predict the amount of syrup that can actually be made in 1942.

Because of the special importance which may be attached to this project at the present time, some further details regarding it are given below.

Production of a Bland Syrup From Apples:

Investigations have been conducted at the Eastern Regional Research Laboratory with the view of eliminating the substances that impart flavor, odor, color, and jellification to apple juice, leaving a more or less flavorless sugar solution, that can be evaporated under vacuum to a syrup somewhat similar to commercial invert syrup, which is well known in the bakery, ice cream soft drinks and other food industries. This objective has been achieved to the degree that several industrial users have pronounced the syrup satisfactory, and a number of people have declared it an excellent table and cooking syrup. Because of the present demand for sweetening agents, it is believed the time is time is ripe for producing this syrup. It should be understood, however, that only the major steps in the process have been worked out; a number of minor details require further study. Prospective users of the process will be kept informed of further developments.

The process in general is as follows: The apples are washed to remove spray residues and ground in a hammer mill, and the juice is extracted by means of a hydraulic press. The juice is treated with a slurry of hydrated lime until the pH value is 8, heated to 175°F. (79°C.), and filtered. The clarified juice from the filter press is treated with dilute sulfuric acid (1-3) until the pH value is between 5 and 5.5 and then evaporated to a syrup containing approximately 75 percent of solids.

For some purposes, apple syrup will find its own market on the basis of its merits. For food purposes, it will be valued largely as a sweetening agent, For this, it will be superior to corn and sorghum syrups, about equal to maple syrup, and somewhat inferior to invert syrup and honey. For tobacco products, its sweetness will be less important than its humectant and burning properties. Its value for this purpose will depend largely on the demand, and cannot be predicted at present.

Apple syrup contains the same sugars as honey but in different amounts, having more levulose and sucrose and less dextrose. Thus it is sweeter than honey. Because of this

sweetness and because it has no pronounced flavor, the syrup may be adapted to some uses for which honey is satisfactory. The syrup may cost too much for extensive use in low-priced beverages or in the preserve industry. Moreover, the phosphates and nitrogen compounds contained in the syrup would provide nutrients for the growth of micro-organisms in an unpasteurized beverage. The flavor is also apparent in some beverages when appreciable amounts are used. Ice cream offers a definite possibility for using the syrup to replace part of the sugar in the mix. Its hydroscopicity suggests the use of apple syrup as a humectant in place of glycerin in conditioning tobacco. Some sugar is used at present for this purpose and levulose has good burning characteristics. Several tobacco companies have tried it in pipe, cigarette, and chewing tobaccos, and now wish to have a source of supply developed. The bakery and confectionery industries are being supplied with samples and may also be expected to consume appreciable quantities.

There are also possibilities in the sale of concentrated apple juice for redilution with carbonated water to form a beverage. The product could also be used in bakeries, in jams, jellies or preserves, for vinegar or brandy manufacture, and for confectionery purposes. Pilot-plant equipment of the most modern improved design* is now being installed at the Eastern Laboratory to study the concentration of apple juice by low temperature evaporation in a vacuum evaporator, and to recover the volatile flavoring esters.

The evaporator is designed to preclude the possibility of local overheating and injury to the concentrate. Because of the foamy characters of the liquids being handled a separator has been designed which ensures complete separation of the liquid and vapors. A vertical type condenser is used with the headers, tube sheets and tubes made of stainless steel of the type used in the rest of the unit. A cooler is interposed between the condenser receiving tanks and consists of a coil immersed in an open top cylindrical tank. Two receiving tanks are provided for catching different fractions of the concentrate.

A survey has been made of the carotene (pro-vitamin A) content of a wide selection of leafy vegetation, the object of which is to find rich sources of carotene, preferably waste byproduct materials, from which to prepare concentrates of carotene, or pure crystalline carotene, for use in human foods and live stock feeds. Broccoli, lima bean and beet leaves have been found to be particularly good sources of carotene. Experiments are underway to develop commercial processes for preparing carotene concentrates from such materials.

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* A blueprint may be obtained from the Chemical Engineering and Development Division, Eastern Regional Research Laboratory, United States Department of Agriculture, Philadelphia, Pa., U.S.A.

IV. THE NORTHERN LABORATORY.

The following is a summary of the research programmes of the various divisions in this laboratory:-

Fermentation Division:-

To the Fermentation Division has been assigned the problem of converting the commodities, corn, wheat, and agricultural residues, into useful industrial chemicals by means of fermentation processes. It is possible, in this way, to produce dozens of potentially valuable substances. For instance, ethyl alcohol, butyl alcohol, acetone, and citric, lactic, gluconic, and substituted bluconic acids are examples of chemicals already produced by fermentation. No work will be done by this Division on alcoholic beverages. In connection with this project, and as a necessary adjunct, a collection is being made of potentially useful yeasts, molds, and bacteria, this collection having already reached the size of several thousand species and strains of microorganisms.

Agricultural Motor Fuels Division:-

The Agricultural Motor Fuels Division will operate a modern Fermentation plant having a capacity for producing 500 gallons of ethyl alcohol per day, or equivalent quantities of other chemical substances producible by fermentation. This plant is not intended for quantity production, primarily, but will be used to study yields, and processing costs, using a variety of agricultural materials (many of which have not been used heretofore commercially), and a wide range of process conditions. Such work is intended to evaluate the available crop surplus materials as fuel sources, at the same time attempting to effect economies in production cost. At present, fermentation products from grain are too expensive to compete directly with petroleum fuels.

Production of fuels of agricultural origin, other than by fermentation, will also be attempted. For example, the Division will study the feasibility of generating producer gas from corn cobs or other similar agricultural residues. This gas might be used for fuel and light in homes, or for motor power in internal combustion engines on farms or in factories where such materials are available. Experiments will also be conducted on the possible enrichment of known fuels by means of suspensions of carbonaceous matter. It is intended to make engine tests of all kinds on fuels, both for determining comparative economy and for securing optimum running conditions.

Agricultural Residues Division:-

The work of the Agricultural Residues Division consists of developing, from such materials as stalks, straw, hulls, and cobs, new products and improved methods for the production of previously developed products. In general, agricultural residues are of a fibrous character. The first approach to their utilization is to manufacture them into useful articles, such as building materials, fillers, etc., with as little chemical processing as possible. Chemically, these residues consist of cellulose, hemicelluloses, and lignin, and are suitable, therefore, under proper economic conditions of collection, storage, and processing, for the manufacture of paper pulp, alpha-cellulose used to make rayon, and cellulose plastics; for lignin and associated plastics used in the electrical, automotive, airplane, and building industries; for the fermentation industries in the making of solvents; and for the manufacture of complex organic chemicals. Processes of this general type will be carried through the laboratory and pilot-plant stages looking toward industrial production.

Starch and Dextrose Division:-

Research work of the Starch and Dextrose Division will be conducted in the following broad fields; The properties of the starch granule at the various stages of its development; the properties of starch as influenced by the conditions of storage of the grain, and by processing for the production of starch; the structure and composition of starch granules; the modification of starch by physical and chemical agents: the structure of starch, modified starch, and starch derivatives; those properties of starch, starch granules, and starch derivatives which determine their use in particular industries; and the modification of dextrose by physical and chemical means, and determination of the properties of dextrose derivatives. In particular, such fundamental and practical information will be obtained as is required by industries for extending and developing new uses for starch and dextrose.

Analytical and Physical Chemical Division:-

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The Analytical and Physical Chemical Division has been organized to carry on studies on the composition of corn, wheat, and agricultural residues as affected by such factors as origin, variety, season, storage, disease, condition, etc.; service work of an analytical nature for the other divisions; and fundamental research in fields that will give information of basic value to the work of the other divisions. The purpose of the studies on composition is to make possible the selection or development of varieties with a maximum of desirable properties for any particular industrial utilization.

Oil and Protein Division:-

The work of the Oil and Protein Division is divided into two fields of research indicated by its name. The oil work includes investigations in the field of polymerization phenomena to develop new and extended uses for vegetable oild and is divided into the following projects: the composition, processing, and industrial utilization of corn, and wheat oils; the utilization of corn, and wheat oils and derivatives of their fatty acid components for surface coatings; and isomerization, dehydrogenation, separation, and polymerization studies on derivatives of corn and wheat oil fatty acids with particular regard to utility of the products. The protein work of this Division consists of research on the development of methods for the commercial isolation of proteins, protein fractions, protein components, or their derivatives, from corn or corn processing residues, and on the development of uses for these materials.

Commodity Development Division:-

The functions of the Commodity Development Division are: to collect grain and agricultural materials for use by the other divisions in their researches; to make field studies for determining the condition, supply, and availability of the various grains and agricultural residues for industrial use; to obtain industrial market information needed by other divisions in the development of new products from the agricultural materials with which they are working; to integrate the work of the Laboratory with that of the Bureau of Plant Industry, U.S. Department of Agriculture, and the Agricultural experiment stations in the development of new strains, or methods of culture, for the production of corn and wheat possessing those particular qualities best adapted for industrial purposes; and to compile and correlate data resulting from the experiments of the Laboratory.

Engineering and Development Division:-

The Engineering and Development Division will be concerned

with engineering problems connected with the production of special equipment needed for research purposes and with the development of processes of production, and in many cases will carry out pilot-plant operations on laboratory processes.

Since the outbreak of war the programme of this laboratory has been completely changed, and is now almost entirely concerned with investigating the possibilities of utilizing agricultural materials for the production of war essentials. We need many raw materials for the manufacture of strategic materials which the farm can provide, e.g. alcohol, glycerine, acetone, butyl alcohol, and butylene glycol; vegetable oils, including linseed, sunflowerand rapeseed; fibres, including flax, hemp and protein fibres. Because of the urgency of some of the problems, certain phases of the research work at the Northern Laboratory are proceeding at a pace which could not have been achieved in normal times. There is every reason to believe that these developments will be beneficial to agriculture in normal times.

Research in Progress: (i) Production of Butylene Glycol by Fermentation.

Scientific cultivation of micro-organisms to effect desired biochemical changes which result in the production of definite chemical compounds for industrial and other uses has been receiving increased attention during the past 40 years and is now of considerable industrial importance. In general, carbohydrate materials such as starch or glucose which can be derived from commodities such as cereals and potatoes are employed in such fermentations as the starting substance from which a wide variety of chemical substances is obtained. Many chemical compounds have been isolated and identified as the products of both molds and bacteria gro grown on various substances, thus fermentation processes hold great promise for the development of new and extended uses for starchy materials.

One of the original problems studied in the Fermentation Division of the Northern Laboratory was the production of butylene-glycol from glucose by bacteria of the genus <u>Aerobacter</u>, first investigated on this continent by Fulmer and Workman at Iowa State College. This work was undertaken because it was felt that butylene glycol by itself would find a number of important uses in industry. It is practically a new compound with many of the characteristics of glycerol which it might replace in many uses. Freezing point curves of mixtures with water indicated that it could replace ethylene glycol as a constituent of anti-freeze compounds. It shows interesting possibilities as a deicing agent or as a coolant for airplane engines and there appeared to be no doubt that it would find application as a solvent in a number of commercial processes.

However, intensive work on the production of butylene glycol began with the realization that it could be readily converted to butadiene, a substance in urgent demand for the production of synthetic rubber. In the remarkably short time of less than six months, the workers in the Northern Laboratory, working in close co-operation with the research staff of Joseph E. Seagram and Sons Inc., Louisville, Kentucky, have perfected a process for the production of butadiene from butylene glycol which is produced by the fermentation of corn or wheat. The process has passed the pilot-plane stage but is still untried commercially, although plans have been prepared for a plant to produce 200 tons of butadiene per day from 55,000 bushels of grain.

If production were begun immediately the yield, based on present knowledge would be 6.4 pounds of butadiene per bushel of grain and it is believed that a yield of 8.2 pounds per bushel would be reached. The maximum yield per bushel of butadiene from ethyl alcohol is 5.5 pounds of only 85% purity and from butyl alcohol (also produced by fermentation) only 2.1 pounds of butadiene of very low purity, are obtained from a bushel of grain.

Donald M. Nelson, Chairman, War Production Board, testifying on July 14th, 1942, before the Subcommittee of the Senate Committee of Agriculture

and Forestry investigating the production of synthetic rubber, commented on this project as follows: "I am particularly interested in and have given all the encouragement I can to the development of the butylene-glycol process now under test by the Northern Research Laboratory". If this process had been developed to its present stage six months ago it would probably have been given a large allocation in the 800,000 ton per annum synthetic rubber program. If new plants are to be constructed for butadiene production, this process will probably be included in the program. It not only offers the highest yield of butadiene per bushel of grain, of a very high purity, but the butylene-glycol can be produced by existing alcohol plants and the construction of the plant to convert butylene-glycol to butadiene would require very small amounts of strategic materials, steel, copper, etc., as compared with petroleum plants. These plants will also be producing a new chemical which will later find extensive peace-time uses.

The present status of the butylene-glycol - butadiene process is briefly as follows:

(I) BUTYLENE-GLYCOL FERMENTATION

(a) Seagram's Process:-

Aerobacter aerogenes is used as the fermenting agent. This organism ferments glucose, maltose or sucrose but is not able to hydrolyse and ferment starch and dextrin. Furthermore it cannot maintain a fermentation in competition with contaminating organisms hence, mashing procedures employing malt diastase, as practised in distilleries, cannot be used as they do not yield a sterile mash. Saccharification of the starch is therefore carried out with sulphuric acid.

The grain, either corn or wheat, is ground in a suitable mill and mixed with a continuous stream of warm (145° F) dilute sulphuric acid to give a concentration of 2N (10%) acid in the cooked mash. The mash is then passed through a continuous cooker of the steam-jet exhauster type (these vacuum injectors are manufactured by Schuttle and Koerting Co., Philadelphia) where it is instantaneously heated to 180° C by means of 170 lbs. per sq. inch steam. During this interval of about 3 - 4 minutes the starch is completely hydrolyzed to fermentable glucose.

Simultaneous with the hydrolyses a slurry containing 20% calcium carbonate is prepared in a continuous system consisting of an automatic weighing-feeder and mixing vessel into which hot water is also metered. This slurry is heated to 149° C. in a steam jet heater and held at this temperature for 5 minutes to effect sterilization.

As the hot, acid-hydrolyzed mash is dissolved from the cooker vessel, this heated calcium carbonate slurry is added to neutralize the mash and to give an excess equivalent to 2-5 grams per liter. The discharge from the continuous cooker is blown down to a lower pressure (40 lb) in an exhaust tower which immediately cools the mash to 116° C. This tower has the advantage of recovering 50% of the heat and makes possible a definite steam draw and hence a continuous load on the boilers.

The hot neutralized mash is pumped through a water cooled tubular mash cooler in which it is cooled to the fermenting temperature of 30° C. The mash is at a pH of 6.2, is completely sterile and the starch is completely hydrolyzed to fermentable sugar.

The sterile hydrolyzed mash is pumped into the fermenter urea added, and the temperature controlled at 30° C; a 5% inoculum of a pure culture of *Aerobacter aerogenes* is then added. The mash is aerated in the fermenter by means of sterile air passed through carbon spargers located in the bottom of the fermenter and the fermenter

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

is kept at a positive pressure of 2 lbs during the course of the fermentation in order to minimize the danger of contamination. Fermentation is usually complete in 42-48 hours. A continuous fermentation process may be used whereby all equipment is synchronized with the rate of fermentation i.e., milling, cooking etc. so thta fresh mash is fermented at the same rate as it is prepared.

The beer, containing 5.3 - 5.6% butylene-glycol; 2 - 6% ethyl alcohol and 1 - 2% acetyl methyl carbinol, is pumped directly to the unit for recovering the butylene-glycol. A bushel of corn gives 16 pounds of butylene-glycol.

(b) Process developed in Northern Regional Laboratory:-

In view of the limitations of the process utilizing Aerobacter aeorgenes (see above) they have developed a process based on the use of an organism - Aerobacillus polymyxea # 510 - which can utilize starch directly.

In this process 0.5% of malt is added to a 25% corn or wheat mash (i.e., 20 gallons per bushel of grain) and allowed to act until the mass is liquified. The slurry is cooked by direct steaming at 10 lbs. pressure for 1½ hours, cooled to 30°, adjusted to pH 6.5 by adding 0.5% calcium carbonate and inoculated with an inomulum of aerobacillus polymyxea. The fermentation is allowed to proceed for 5 days without aeration or stirring.

The beer contains 4% of butylene-glycol and one bushel of corn gives 10.5 lbs. butylene-glycol, 6.5 lbs. ethyl alcohol and 0.2 lbs. acetyl methyl carbinel. The butylene-glycol pilot-plant in the Northern Laboratory is now using 200 bushels of grain a day.

II RECOVERY OF BUTYLENE/GLYCOL

A counter-current, liquid - liquid extraction with butyl alcohol is being used by Seagram's. The fermented beer is adjusted to pH 8.0 - 8.5 with lime, heated to 100° C for 15 minutes and filtered through an Oliver Rotary Filler. This removes certain solids and proteins which cause emulsion formation during the extraction with butyl alcohol. The extraction of the butylene-glycol from the beer is carried out at 70-80° C in a tall column which is equipped with baffle-plates, the beer being introduced at the head of the column and the butyl alcohol forced in under pressure at the bottom of the column. The beer discharged from the bottom of the column contains no butylene-glycol and the butyl alcohol taken off at the head of the column contains 2.7% by weight of butylene-glycol. Two rectifying stills are employed, one to recover the butyl alcohol from the beer and the other to separate the butylene-glycol from the butyl alcohol extract.

Pilot plant experiments using relatively crude equipment, gave an overall recovery of 90 - 95% of the butylene-glycol present in the beer. Using large scale equipment specially designed for the process, a constant recovery of 95% is anticipated.

Seagram's are now experimenting with a spray-drying process such as has been developed by the U.S. Industrial Chemicals, Inc., for recovering glycerine in alcoholic fermentation. The butylene-glycol would be extracted from the vapors and gases and the residue would be reduced to a dry powder suitable for feed or fertilizer.

The Northern Laboratory has concentrated on distillation studies, instead of the butyl alcohol extraction process since, in the latter process, distillation is necessary anyway in order to recover the solvent. Butylene-glycol behaves somewhat like glycerine and can be separated from impurities by steam distillation.

The beer is limed to pH 8-9, filtered or centrifuged, and fed continuously to a steam-jacketed still, the vapors from which enter a continuous rectification column about midway between the top and bottom. At the beginning of the distillation only water vapor passes to the column, and the process is one of evaporation quite similar to that encountered in the recovery of glycerine. When butylene-glycol appears in the vapor, water is refluxed to the top of the column and rectification takes place with water vapor passing to the condenser and butylene-glycol collecting in the bottom heated section of the tower, from which it may be removed. After all the beer has been added to the still, open steam is admitted for the purpose of removing additional butylene-glycol. The overall recovery amounts to 92.8% of the butylene-glycol originally present in the fermented liquor.

(III) CONVERSION OF BUTYLENE-GLYCOL TO BUTADIENE

Very little success has been obtained with catalytic methods for the direct conversion of butylene-glycol to butadiene. Both laboratories have been working on a process which involves the reaction of acetic acid with butylene-glycol to form the diacetate which is converted to butadiene by pyrolysis.

Esterification of the butylene-glycol is a relatively simple and straightforward procedure. Seagram's have found toluene and sulphuric acid to be the best entrainer, p-toluene sulfonic acid is formed, which in itself, is an excellent catalyst and gives higher yields of the diacetate i.e. 88-95%, depending on the efficiency of the column, and of 97-99% purity.

Pyrolysis of the diacetate is performed by passing the vapors through hot tubes at an optimum temperature of 575-600° C. (Seagram's-steel tube) or 475-550° C. (Northern Laboratory - glass tube), without any catalyst present. The first pass gives a 78% yield of butadiene, of excellent purity, accompanied by a small amount of unchanged diacetate, a large amount of acetic acid, and some vinyl methyl carbinol acetate which may be considered an intermediate product.

The acetic acid is recovered from the mixture and used to react with fresh butylene-glycol to form more diacetate. The monoacetate and the unchanged diacetate from the first pass are separated and returned to the charging stock entering the reaction tube to yield more butadiene. The monoacetate and acetic acid have boiling points very close together and it is difficult to get efficient separation. It is hoped that improving this step in the process will give a 90% yield when the material is recycled through the pyrolyzer.

It is claimed that, by the butylene-glycol process, butadiene can be produced for 18 cents a pound from corn at 85 cents a bushel. The capital cost of a plant, with capacity to produce butylene-glycol and butadiene equivalent to 100,000 tons of rubber per annum, is estimated to be about $20,000,000.

(ii) Power Alcohol

The biggest proposal considered in the survey of Canadian research on the utilization of farm products made by the National Chemurgic Committee was the production of alcohol from grain, potatoes etc. for use as a motor fuel. No other project would have contributed to the same extent to the relief of the surplus wheat situation.

A review of this extremely complex and controversial subject may be found in the Committee's report[x] so that there is no need to discuss it fully at this time, but simply present some supplementary observations.

The value of "power alcohol" as a motor fuel is well known but the cost of production is higher than that of gasoline. It was concluded in the report that the project was not economically sound and that the expediency of instituting a "power alcohol" industry in Canada depended on whether the net advantage to agriculture and to the country as a whole outweighed the increase in cost of the motor fuel. Some of the factors considered were economic and to some extent measurable whereas other important factors were social in nature or involved National policy.

The extra cost of a power alcohol industry had to be weighed against resulting benefits. Thus, even if costs were likely to be abnormally high, if benefits were correspondingly great, development of the industry would have been warranted. Security of supplies of liquid fuel in war time and any other contribution to the security of agriculture, might have justified heavy costs. If both ends could have been achieved to a sufficient degree by "power alcohol" production, extra cost would have been of secondary importance.

The argument most commonly raised in favor of the scheme is that, notwithstanding the important effect of higher costs, extension of alcohol production for use as fuel is justified because of the inevitable decline in known world oil resources and consequent increase in price. It can be calculated, from American Petroleum Institute estimates, that if no new oil fields were discovered subsequent to 1940, or no new methods of recovery were developed, the "proven oil reserves" will meet all domestic demands only to 1955. Of course, constant effort is being made to discover oil and no one can predict what the outcome will be. When petroleum reserves are insufficient to meet increasing requirements then gasoline can be made from coal and shale, but so far as we now know, this would be very expensive.

If alcohol is to be used for motor fuel it can be made from ethylene which costs practically nothing but the alcohol made therefrom costs about 13 cents per U.S. gallon. The cost of manufacturing alcohol from grain by the malt process is about 9.0 cdnts per U.S. gallon. The overall cost of producing alcohol in a plant with a capacity of 25-50,000 gals. per day may be reasonably estimated at about 42 cents per U.S. gallon, if corn or wheat, at 85 cents per bushel and malt (10%) at $1.20 per bushel are the raw materials and if the yield of alcohol is 2.5 U.S. gallons per bushel of grain and the dry by-product feed sells for $30. per ton. The cost of gasoline at the refinery may be in the neighborhood of 5 - 10 cents per U.S. gallon. These figures serve to illustrate the degree to which agricultural products fall short in competing with petroleum and natural gas as raw materials for industry.

A number of alternative proposals have been made, for example, instead of fermenting the whole wheat it might be more economical to mill it, so as to recover constitutents of commercial value such as the bran, germ and gluten and manufacture alcohol from the residual starch. The success of such a scheme would depend upon finding larger and more profitable markets for the germ and the gluten as human food, so that the starch might become a cheap by-product analogous to molasses. Wheat is the least desirable farm product for industrial uses since its economic value is determined by its value as a human food.

The production of cereal starch and alcohol in the same plant might lower costs. Taking all of the starch out of the grain is expensive but taking out 25% of the starch is a relatively cheap process - the rest

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[x] Published May 1941 by the Canadian Chamber of Commerce, Board of Trade Building, Montreal.

could be converted over to alcohol. The success of this plan will depend upon a wide expansion in the present industrial utilization of starch and there is every indication that this can be achieved through research.

Much more radical and far reaching suggestions are made by Mr. Herman F. Wilkie, Vice-president, and Dr. Paul J. Kolachov, Director of research and development, of Joseph E, Seagram & Sons Ltd., in a treatise to be published shortly on "The Utilization of Farm Products for the Production of Ethyl Alcohol-Farm Motor Fuel as a Means of Solving the Agricultural Problem". They consider fundamentally unsound, any scheme in which the raw material is purchased from the farmer and the blend of alcohol and gasoline sold back to him at a few cents more per gallon than ordinary motor fuel. Prices of farm products fluctuate so frequently and so widely that an alcohol industry has difficulty in grossing a steady profit; the cost of blending is dependent upon the sale of the by product feed to the farmers.

They propose to manufacture 190-proof alcohol (95% alcohol) in community distilleries - an extension of the antique practice of community milling - to be used as motor fuel in the farmers' tractors. The International Harvester Company has manufactured tractors and trucks for use in the Philippines which run on 190-proof alcohol and are not materially different from those operating in this country.

The farmers would bring their surplus farm products and unmarketable accumulations to the distilleries and would take away ethyl alcohol and stillage (residue from alcohol manufacture) in amounts proportional to the raw material brought in, the latter to bd used as feed or fertilizer. In this way, everything returns to the farm and soil fertility is conserved. The distilleries could be financed by communities and farmers cooperatives or by a Government loan - not a subsidy - that would be constructive and eventually pay for itself.

They are also conducting research to perfect a mobile distillery to operate in the farmyard. They believe that manufacturers of agricultural implements should give some thought to the project and consider how it can be incorporated in a post-war agricultural program.

The production of industrial alcohol was increasing rapidly in peace-time and in the future our needs will undoubtedly increase with our chemical progress, nevertheless there have been no noteworthy improvements in production methods during the past twenty years. The tremendous increase in the demand for industrial alcohol for the manufacture of munitions had been a great stimulus to research on alcohol production.

(iii) Alcohol Production Research

Research is actively in progress in the United States to reduce the cost of producing alcohol from farm products. The Northern Laboratory is studying the fermentation of different cereals using a pilot-plant which has a capacity of 500 gallons per day. It is constructed of most modern equipment and can be adapted to the investigation of any raw material and process. (see photographs).

The Century Distilling Company, located in the same area, has recently made important improvements in processing corn and wheat. A cold-water extract of malt, sterilized with formaldehyde, is used for saccharification. The malt residue is returned to the cookers containing the ground grain and the mash gelatinized by cooking. Yeast fermentation can now be done under sterile conditions. Due to the greater liquefaction of the mash it is now possible to use a more concentrated mash in the fermenters. A yield of 2.8 (U.S.) gallons of alcohol per bushel of corn is obtained in plant-scale operations.

Joseph E. Seagram and Sons, Inc., Louisville, Kentucky, have revolutionized plant design and operation, having developed a continuous

cooking and mashing system for cereal grains. (This process has already been referred to when discussing butylene-glycol fermentation). Gelatinization and saccharification of the starch takes place in the pipe-line system, with remarkable rapidity, and the fermentor is designed for continuous operation. The fermentation process now in use in molasses plants (i.e. the "batch" process) has a 50 hour fermentation cycle requiring several fermenters; the new "continuous" process has a 4 hour cycle and required one fermenter. Twenty-five percent of the volume of the charge in the fermenter is drawn off each hour and a fresh 25% added. The fermentation time for grain is cut from 80 hours to 8 hours. They believe that 85% of the fermenters now in use can be eliminated. The simplification in equipment effects a great reduction in capital cost. They have also developed a continuous process for the production of pure culture distillers' yeast which eliminates over 75% of the existing yeasting equipment. There is also room for great improvement in the thermodynamic efficiency of the ordinary still which is said to be only 6%.

A unique feature of the new Seagram process is that two grades of by product feed are procured. The slop is filtered and the residue dried for cattle feed. The filtrate containing 3 percent solids, is consentrated to 30 percent solids and dried on a rotary drum. The product, referred to as "dried solubles" is sold for poultry feeds and contains 30 percent protein and 25 micrograms of riboflavin (vitamin B_2) per gram when wheat is the raw material. When incorporated in the poultry ration at a level of 6 percent it is reported to be equivalent to 5 percent skim milk powder. This is particularly important to the poultry industry at the present time as skim-milk and buttermilk are extremely scarce. These products are the main sources of riboflavin in the poultry ration.

Yeast does not attach the non-fermentable sugars, or pentoses, in cereal grains and as a result they have been ignored in alcohol manufacture for want of an attacking agent. Workers at Fordham University have discovered how to convert these non-fermentable sugars to alcohol by means of enzymes produced by fungi. Forthermore, it has been demonstrated at Iowa State College and the University of Idaho that common "bread moulds" can be used to convert grain into alcohol with greater speed, economy and efficiency than the customary malt from sprouting barley. Use of these moulds in the alcoholic fermentation of corn and wheat would give about 10 percent by weight more alcohol per bushel than would be obtained with malt.

The Northern Laboratory has made some preliminary investigations of the so called "Moldy Bran Process" and confirmed that increased yields of alcohol are obtained but very definite optimum conditions have to be amintained for satisfactory growth of the mold.

> The moldy bran is produced by inoculating a suspension of wheat bran in an equal weight of 0.2N hydrochloric acid (containing trace elements, iron, copper and zinc according to Steinberg's formula), with <u>aspergillus oryzae</u>. The medium is aerated on a tray for 12 hours at 35-45° C and a heavy micellium growth is obtained. This is broken up by turning over in a slow rotating drum and is ready for use in 24 hours. One-hundred parts of ground grain and 200 parts of water are cooked at 15-20 pounds of steam pressure. An additional two parts of cold water and the moldy bran are added; the mash cooled to the fermentation temperature and the fermentation allowed to proceed for 72 hours.

Instead of using 90 pounds of grain and 10 pounds of malt, the latter costing $3\frac{1}{4}$ cents a pound, this process uses $97\frac{1}{2}$ pounds of grain and $2\frac{1}{2}$ pounds of moldy bran. Normally, wheat bran costs about the same as grain so that the cost of malting is practically eliminated. It is claimed that industrial alcohol can be produced by these new methods for at least 10 cents per gallon less than has been possible before, from the same raw material.

Capital costs for alcohol plants of varying capacity have also been brought up to date by the Northern Laboratory. It is estimated that a 10,000 gallon per day distillery of conventional design would cost one million dollars. This figure is based on a 20 year operation and includes 14 day grain storage (64,000 bushels) concrete bins; by-product drying equipment and storage facilities; water service and power plant including electricity. A distillery designed for corn, which is the easiest raw material to process, will experience some trouble when operating with wheat particularly if the by-product is to be dried. Corn protein isn't gummy and sticky like wheat gluten and doesn't foam to the same extent.

Waste liquors from paper mills and other industrial plants, as well as straw, corn stalks and other agricultural wastes, contain sugars capable of being fermented into alcohol. But the solutions are so dilute that the fuel needed for distillation is worth more than the alcohol that could be obtained. Workers at the Polytechnic Institute of Brooklyn reported to the American Chemical Society on September 18th, 1942, that fusel oil will dissolve the alcohol from these dilute solutions but will not mix with the water, and the alcohol can readily be separated from the fusel oil. The economics of the method, which by-passes the expensive distillation process are said to be such as to permit the profitable use of agricultural wastes for the production of industrial alcohol.

(iv) Alcohol for Synthetic Rubber

Although the Northern Laboratory has not been investigating this subject, it is felt that brief reference should be made to it here. The entire problem was in a state of flux for a considerable time and so many conflicting statements were made that one hesitated to even conjecture what the development would be in the next two or three years, much less what would transpire when the war was over. However, the situation has been clarified considerably by the hearings, held between March 20th, and July 29th, 1942, before the Subcommittee of the Committee on Agriculture and Forestry, United States Senate, relative to the utilization of farm crops for the production of industrial alcohol and synthetic rubber.

The following is a brief summary of the present status of the rubber problem as it appeared to the writer after reading the testimony presented at the Committee hearings [x]:-

> There are several types of synthetic rubber, amongst these Buna-S which has virtually all of the characteristics of natural rubber and is the only type suitable for rubber tires. It is produced by the polymerization of the hydrocarbons butadiene and styrene in the proportion of 4.1. The process is simple but the main difficulty is to obtain one of the starting materials, namely butadiene. The supply of styrene is, or soon will be ample.
>
> Butadiene may be produced from five different starting materials, (1) butylene from gas-oil cracking or through butane from natural gas; (2) ethyl alcohol from grain or from ethylene recovered from refining gases; (3) acetylene from coal plus limestone; (4) butylene-glycol from grain and (5) butyl alcohol from grain or petroleum.
>
> The production of butadiene from alcohol or butylene (petroleum) are established and technically sound industrial operations. The raw material costs per pound of butadiene are about 22 cents using alcohol at 50 cents per

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x Printed for the use of the Committee on Agriculture and Forestry and published in three volumes by the United States Government Printing Office, Washington, D.C., 1942.

gallon and 4 cents using butylene at 12 cents per gallon. Processing costs are probably about the same for the two processes but accurate estimates are not available. The cost of the plant to produce 100,000 tons of butadiene per annum is estimated at $21-25,000,000 for alcohol and $93-100,000,000 for butylene (petroleum).

The various processes for the production of butadiene have been evaluated and selected and a definite synthetic rubber program adopted which calls for the production of Buna-S rubber at the rate of 700,000 short ons per annum by the end of 1943. This is allocated as follows:- 220,000 tons from alcohol as base material; 60,000 tons from isobutylene; 20,000 tons from benzol; 40,000 tons from acetylene and the remaining 360,000 tons from various petroleum products predominately butylene. The total butadiene construction program is 678,200 short ons per year to be completed by October, 1943. The engineering process has been virtually completed and in many cases the actual construction of the plants is well under way.

Approximately 200,000,000 gallons of alcohol will be required in 1943 to produce the butadiene required for the manufacture of 220,000 tons of rubber, (1 gallon of alcohol yields 2.2 pounds of butadiene or 2.73 pounds of Buna-S). Only 10 percent of this will be synthetic alcohol; the rest will be obtained by fermentation. Synthetic alcohol is much cheaper than grain alcohol but its production will not be increased because of the critical materials required to expand the ethylene plants. For the same reason, alcohol will probably be used to make ethylene for the manufacture of styrene and it is estimated 30,000,000 gallons will be required annually for this purpose.

The alcohol situation in 1943 may be pictured as follows:-

	190° Proof Alcohol (Million gallons)
Estimated Needs:-	
Synthetic rubber	210
Other uses	400
Total	610
Estimated Production Capacity:-	
Synthetic	70
Invert and blackstrap molasses	220
Grain	227
Fruit	140
Total	657

To produce enough alcohol for rubber and other uses, entirely from grain, would require 235 million bushels each year. These figures explain why no new alchol plants are being built, the requirements being met by the conversion of existing distilleries. The available grain-distillery capacity is 91 million bushels per year, capable of producing 227 million gallons of alcohol. Further conversions involving 88 million bushels of grain may have to be undertaken should transportation difficulties cut off the supply of molasses entirely.

At the present time the principal advantage of producing butadiene from grain alcohol lies in the fact that less vital metals are required for the plants to carry out this process and furthermore, such plants

will be built in less time than those required for the petroleum process. there appears to be little question but that the process utilizing alcohol from the fermentation of grain could not compete from the standpoint of cost, with the petroleum process under free economic conditions. This is due to the high cost of the initial raw material, grain, which is not compensated for by the yields which have been reported thus far nor by the fact that the alcohol process does offer an advantage in that the butadiene obtained is of higher purity and hence does not require as much purification.

The contracts for the entire alcohol - butadiene program have been placed with the Carbide and Carbon Chemical Corporation, the largest producers of synthetic alcohol. After the war they will obviously operate entirely on synthetic alcohol and the distilleries will return to manufacturing spirits. If we enter the post-war period with no grain alcohol facilities other than the industrial plants now being converted, we may expect that such plants will return to molasses alcohol production rather quickly. Their basic construction is such that they will be much less efficient producers of grain alcohol. The use of grain alcohol is purely a temporary expedient and after the war the ultimate source of all the synthetic rubber will be petroleum and natural gas.

This policy of viewing the petroleum process as permanent and the grain alcohol process as temporary has been criticized as shortsighted when it is obvious that the production of petroleum must be a temporary thing. Another criticism of the program is that the diversion of butylene to the manufacture of rubber will affect the production of 100 - octane aviation fuel. The limiting factor in producing aviation fuel at the present time is not butylene but alkylation plants and isobutane. However, no one knows what future requirements for butylene will be.

The Baruch Committee has just recommended that the War Production Board's present rubber program be increased 223,000 tons to 1,100,000 tons per annum. If this action is taken, more butadiene will be urgently required at the earliest date possible. A substantial part, if not all, of the new requirements will have to be met by plants based on the direct conversion of alcohol, or butylene-glycol, to butadiene as these processes involve the lowest expenditure of critical materials and the plants can be constructed in the shortest time.

To produce the necessary alcohol or butylene glycol would require the capacity of 20 distilleries, each 25,000 gallons per day capacity, and these would have to be built. They would undoubtedly be located in the middle west and designed to use corn or a corn-wheat mixture. This would mean a substantial saving in production and transportation costs, and would lessen the burden facing the nation's transportation system. All of the distiller's grains could be saved and made available for live stock feeding in the locality of the distillery. A modern plant built solely to make alcohol from grain could also recover the oil which makes up about 3 percent of the grain and is a human food that we cannot afford to waste at present whenfats and oils are so scarce.

If post-war conditions made it possible for efficient midwestern grain alcohol plants to operate in competition with Eastern molasses-derived alcohol, the foundation would be laid for a grain alcohol industry which might prove a valuable asset.

(V) Production of Cereal Starches and their Products

Starches from various sources (corn, potatio, wheat, rice, tapioca) are basically the same, although the physical properties may differ widely and the composition apparently only slightly. A fundamental program on one starch - for example, corn or wheat starch - is also applicable in many respects to other starches. Except for uses due to special physical properties, the price of a starch largely determines the market outlet. The question of which starches to be employed for commercial uses is therefore in part an economic one. Nonfood uses of starch and starch

derivatives are many, and a wide expansion of the present industrial utilization of starch seems almost inevitable. Modified starches, dextrins, and glucoses are prepared industrially by heat, exidation, and acidic or enzymic treatment of starches. The unique properties of these products have adapted them to many uses. Glucose, in particular, which is now made in the crystalline condition, has been diverted into many new fields.

One of the main research projects of the Northern Laboratory is the development of new industrial uses for corn. Since one of the important constituents of corn is starch, they have devoted much time to looking into new uses for cornstarch. With the cutting-off of supplies of imported root starches from the East Indies they have accelerated the program considerably, looking particularly toward the utilization of the so-called waxy starch of maize and other cereals.

The annual consumption of tapioca starch in the United States has been about 350 million pounds per annum. The fact that the world's largest cornstarch producer used such large quantities of tapioca starch may be attributed to two factors, price differential and, particularly, the properties of the starch itself. Tapioca starch is considered indispensable in the production of remoistening glues and certain food products. It produces tasteless products and is the leading raw material for high grade dextrins used on postage stamps, envelopes, etc.

Working in cooperation with the Bureau of Plant Industry, Washington, and the Iowa State College Experiment Station, Ames, they have discovered that the starches from waxy corn and certain other waxy cereals possess the physical properties ordinarily associated with tuber starches as contrasted with cereal starches, and can be used in products for which tapioca has been considered indispensable. The unpleasant flavor of tuber starches limits their usefulness. Samples of waxy starch have been submitted to several industrial laboratories which use large quantities of tapioca in the manufacture of adhesives, gums, paper-sizes, and puddings. Results of their tests indicate that, after minor adjustments are made in cooking time, temperature, moisture, content etc., products can be obtained from waxy cornstarch which practically duplicate those from tapioca.

Of the several glutinous or waxy cereals (hybrids of corn, rice, sorghum and barley), corn appears to offer the best possibilities as a commercial source of waxy starch because its other characters are not essentially different from those of ordinary hybrid corn which is already milled on a large scale.

As a result of the cooperative corn-breeding program being carried on, hybrids containing waxy starches are being produced which compare favorable with the corresponding starchy hybrids. By 1943 enough seed will be available to grow 1,500 or more acres of waxy corn.

Starch acetate films comparable to cellulose acetate films (cellophane) have been prepared. Starch would be a cheaper source of raw material and wheat starch is superior to cornstarch. Mixtures of cellulose and starch acetates increase the tensile strength of films prepared with butyl and ethyl phthalates as plasticizers.

Other important projects engaging the attention of the Starch and Dextrose Division of the Northern Laboratory, at the present time are:- (a) high pressure cracking of sugars to produce glycerine and propylene glycol; (b) oxidation of starch and dextrin to produce saccharic acid; (c) pyrolysis of starch to produce laevo glucosan, the dinitro derivative of which is an excellent propellent explosive; (c) preparation of films from starch acetate and chlorinated starches. Some details regarding these investigations are given below.

<u>Waxy Starch</u>:- In some respects waxy and ordinary cornstarch are much alike but the waxy variety is easily recognized by the

reddish brown color it stains with iodine. There is little difference in the size and shape of the granules, B-amylase digestion follows nearly the same course and the limit-dextrins so produced exhibit a close chemical similarity. The gelatinization curves of waxy starch resemble tapioca rather than cornstarch. Freshly prepared pastes of tapioca and of waxy starch are similar in their glutinous, viscous character and translucent appearance, The viscosity at 75° - 90° C of waxy starch is considerably above cornstarch or tapioca. When pastes are cooled, ordinary cornstarch soon becomes opaque and sets to a stiff gel, while waxy pastes, even at concentrations of 20% do not increase a great deal in consistency and remain gummy and viscous for days. As yet no starch other than the waxy starch has been found that can be used to make food products similar to minute-tapioca. The yield of starch from waxy corn is lower, the small granules being washed over the table.

Starch Structure:- The properties and structure of native starches as affected by soil, age of plant, storage and climate are being studied by photomicrographs and gelatinization curves. Pilot-plant processing studies on the separation and recovery of starch are being made on the various samples. Storage of grain over long periods weakens the gluten which may be advantageous in the mechanical separation of the starch.

Starch Conversion:- The fundamental aspects of the preparation of dextrins are being studied to get away from the rule-of-thumb methods which prevail in industry. The effects on dextrinization of variety of starch and other variables is being studied. Standardized formulas and methods for blending dextrins for various adhesives etc. are being sought as 8,000 different formulas are now used in the industry. Dextrin from waxy corn is comparable to tapioca dextrin - paper coatings made therefrom are not brittle like ordinary cornstarch films. Wheat and ordinary corn dextrins make adhesives which are dark and poor tasting.

Decomposition Products of Starch:- The reactions involved in processing starch industrially are depolymerization changes, hydrolytic reactions, exidation reactions and thermal decomposition. The preparation of tartaric and saccharic acids from starch and dextrin by oxidation with nitric acid is being studied. The saccharic acid is obtained as a syrup and has yet to be crystallized. It might be modified to make polymeric materials suitable for continuous filaments like Nylon, or used to substitute for citric, gluconic, and tartaric acids in foods. Its value in plastics, like citric or tartaric acid, and its use in the dye industry has still to be determined. A better yield of saccharic acid (40% yield of 95% purity) is obtained from dextrose than from starch. The nitric acid used in the oxidation can be recovered. Studies are in progress on the high-pressure cracking of sugars in a hydrogenation autoclave. Yields of 30% glycerine and 55% propylene glycol have been obtained and may be increased by studies on catalysts and conditions. An unidentified non-glucosan fraction is also obtained. The most difficult problem is to separate the glycerine from butanes. The use of propylene glycol in plastics and as a glycerine substitute and the question of preparing glycerine of dynamite quality are being considered. Other problems under investigation are: (a) the alkaline degradation of dextrose under oxidizing and non-oxidizing conditions to get triosos which might be converted to glycerine and, (b) the production of 1, glucosan by heating starch to 300° - 400° C under vacuum; distilling the oil and crystallizing the product by extracting with acetone in which 1, glucosan is insoluble. A use may be found for 1, glucosan in plastics; the nitrated product is a good propellant explosive. Waxy corn yields 45% of 1, glucosan whereas ordinary corn yields only 30%.

(vi) Industrial Utilization of Agricultural Residues

The most important problem in connection with the utilization of agricultural wastes is their economic collection and segregation. Although farm wastes are intrinsically of little value, collection costs are generally high. Agricultural engineers recognize this and are actively engaged in studying the problem of cutting down these costs. Once collected and brought to the plant, the problem arises of storage for a relatively long period. The industrial utilization of agricultural residues will never be developed on a profitable basis by utilizing the methods employed by the wood pulp industry, where cellulose is used and everything else discarded. The problem must be attacked on several fronts, the ultimate goal being the coordinated utilization of cellulose, hemi-cellulose and lignin etc. Special consideration must be given to pilot-plant operations by men with industrial experience.

The war has again brought to the fore, the question of using straw as a raw material for supplementing wood in meeting a cellulose shortage. Economic considerations have been mainly responsible for the fact that straw has been used only for paperboard manufacture and then only to a very limited extent. Straw is being used increasingly in Europe for paper manufacture under war conditions. One mill in England which used wood pulp and esparto is now using 400 tons of straw per week to replace part of the wood pulp and all of the esparto.

The Agricultural Residues Division of the Northern Laboratory has been investigating three of the most important questions involved in any reconsideration of cereal straw as a source of cellulose, (a) availability, (b) quality, and (c) methods and costs of collection. A short review of their findings is given below.

Cereal straw as a source of cellulose.

The largest industrial use of straw (6 to 7 hundred thousand tons), mainly wheat straw, is for the manufacture of corrugating strawboard. Because of unanticipated straw requirements, at least during the past two years, such straw has contained a certain amount of oat straw. Ordinarily strawboard manufacturers do not want oat straw, claiming that it gives an inferior product and a lower yield. Oat straw is more valuable than the other straws for feeding and bedding purposes and is not so suitable as a source of cellulose because of its high chaff content. Some straw-board mills will not accept more than a small percentage of oat straw and deduct for the amount present. Operators of straw-paperboard mills state that rye straw is probably superior to wheat straw for producing a stiff corrugating paperboard, while neither barley nor oat straw is desirable.

Attention should be called to the greatly increased use of seed-flax straw by the new and thriving American cigarette paper manufacturers. This use of a special fiber to produce a special result in papermaking, not produced by wood fibers, points to a logical use of other cereal straw fibers for cellulose purposes, namely, for specialty papers. The seed-flax straw, generally cut by a binder-harvester, shocked, threshed, and baled from the stack, must be shipped to tow mills to remove the woody portion or shive from the bast-fiber or tow. The shive constitutes about 80% and the tow 20% of the straw. The tow, which is the only portion used in cigarette papermaking, is baled and shipped to the eastern seaboard. The tow from fiber-flax processing may be used for cigarette paper manufacture. With increasing flaxseed production due to the war, larger tonnages of seed-flax straw will be available. Improvement of methods and lowering of costs of collection may be expected. Many attempts have been made to utilize the flax shive, so far without any outstanding success. While about one million tons of straw find an industrial outlet, mainly in the manufacture of cellulose products, many times as much is available. The mulching methods of water and soil conservation which have recently been developed

will undoubtedly widen the use of these cereal straws on the farm in some regions, but we can confidently expect a tremendous potential raw material reservoir, annually replenished, of such cellulose raw materials. With increased farm production consequent to war conditions these supplies will increase. England, Germany, Russia, and others of the war-ridden nations have turned to straw and other residues to assist them in their cellulose economy.

> Physical and chemical analyses of the various parts of wheat straw showed that the less valuable portions of the straw from the standpoint of pulping are the chaff, the heads, and the leaf blades, while the most valuable portions are the stems. Different varieties of straw vary considerably in the proportion of stems to chaff, heads and leaf blades. Physical and chemical examination of combine-harvested straw and stubble after 35 days' weathering in the field showed practically no loss in valuable constituents for pulping purposes.
>
> Present-day methods of harvesting and collecting straw have been investigated and their costs and economics in comparison with those of older methods of using farm stack-straw determined. It is found that on a $6.00 delivered price for farm stack-straw about $1.00 of the cost is represented by the chaff. Chaff is almost entirely eliminated by the use of combine-harvested straw and the use of such straw should, therefore, bring about a saving in pulping operations. Recent improvements in harvesting methods and equipment, including "pic-up" balers, indicate possible savings of approximately $1.00 per ton in straw collection. Based on the use of straw of lower chaff content, lower collection costs due to better methods and decrease in transportation costs, a scheme is suggested that will enable both the farmer and the pulp mill operator to receive benefits of approximately $1.50 each per ton of straw and still maintain the price of delivered straw at $6.00 per ton.
>
> If farmers within an average $1.50 per ton hauling radius (in preference to those supplying stack-straw from the present average $2.50 radius) were paid $1.00 more for unbaled combine-straw or stubble, then the delivered price to the mill would still be $6.00 per ton since the extra $1.00 paid the farmer is saved in hauling charges, which were a part of the f.o.b. price. Thus the farmer and the mill would each receive $1.00 per ton more from the increased value of combine-straw. The farmer would probably not deliver less straw per acre than would be obtained from stack-straw, taking into account actual losses in storing and baling stack-straw. The mill would profit even more than the farmer due to lowered operating costs and improved yields with combine straw. This still leaves $1.00 per ton which may be saved in lower baling costs. By a community of interest this saving might be split between the mill and the farmer.

The Northern Laboratory is also interested in the possibility of developing rural industry engaged in the manufacture of building materials from farm wastes as part of a post-war scheme for improving rural housing. Specifications are being worked out for the small-scale manufacture of wallboard, structural insulation and other building materials. Similar schemes might well be considered in Canada. Deplorable housing conditions prevail in many rural areas in the Prairie Provinces, practically no farm home is insulated and the number of city homes that are, is comparatively small.

Small pulping operations as a community cooperative enterprise and the production of crude furfural at elevators might also be feasible. It is also possible that a more economic utilization of corn might be effected through a scheme whereby the whole corn stalk would be cut and shipped to a central plant (community owned and operated) where the kernel, cob and

straw would be separated; the kernel used to manufacture alcohol; the straw and cobs used partly as fuel in the alcohol plant and partly to manufacture strawboard, furfural etc.; the distillery slops and furnace ashes returned to the farm for feed and fertilizer.

The reactions of furfural, a material derived from farm wastes such as oat hulls and corncobs, are being studied to see if they can derive a substance similar to butadiene which could be used in polymerization reactions to obtain rubber-like materials. Furfural is produced commercially in large quantities from oat hulls.

Interest is also being shown in a powdered fuel system for internal combustion engines and internal combustion turbines invented by William J. Caldwell, Kansas City. The equipment designed is an extra, automatic, ballasted powdered-fuel-feeding system and is equally applicable to an automobile, truck or stationary engine. It is claimed that 2½ pounds of agricultural-waste, finely ground, is equivalent to 1 pound of gasoline.

A cork substitute has been developed but the composition and process has not been divulged. Samples of the material have been found satisfactory in every respect for crown-seal cork. Other important uses will no doubt be found for this product as a substitute for imported cork which is no longer procurable.

A new use for woody remnants from flax treated to make linen has been reported from England. The material is powdered and used as filler for phenolic Bakelite molding powders, flexible board, rubber products, linoleum and other manufactures, for which it has proven a cheap product. A catalytic process has been developed to speed up the removal of wood constituents surrounding the flax fibre. It is hoped to produce, by plant breeding, a special type of linseed which gives a short but strong fibre and at the same time yields large quantities of oil, but at present agricultural research stations are far from producing a satisfactory plant.

(vii) Oil and Protein Investigation

In the search for rubber substitutes with less exacting requirements than tires and for extenders that can be mixed with natural rubber to make it go further, the chemists of the Oil and Protein Division of the Northern Laboratory have produced a rubber-like substance from vegetable oils that looks extremely promising. It has the appearance and feel of natural rubber; has a tensile strength of 3,000 pounds and a 200% stretch compared with the 600% stretch of real rubber. This rubber substitute, made from soybean or corn oil, has passed laboratory tests successfully and is being tested in the pilot-plant.

The process has not been disclosed but it is understood that the main steps consist in separating the more highly unsaturated fraction of the oil by a continuous counter-current extraction using a selective solvent. This fraction is heat polymerized and treated in a manner comparable to the vulcanizing of rubber. The process is essentially an adaption and improvement on methods already in use for preparing rubber substitutes of the nature of "factice" which is produced by the action of sulphur or sulphur chloride on vegetable, fish or other oils. Materials of this kind have been used to some extent in the rubber industry for a number of years and may now come into greater demand. Full utilization of this important development may be impossible at the present time because of the limited supply of vegetable oils.

Ordinarily the Oil and Protein Division is primarily concerned with the utilization of corn oil and protein. The yellow corn kernel contains about 10.6% protein and 5.9% oil. Crude corn oil is used for industrial purposes (black grease, soap, artificial rubber, paint, varnish, glycerine, cotton softener) and refined corn oil is used for edible purposes (frying and cooking, shortening for bread and pastry, salad oil, corn popping and in medicinal preparations).

The variations in composition and character of corn oil derived from different types of corn and produced by different methods of processing, are being studied. Reactions and processes are being investigated with the object of improving present uses and developing new outlets for corn oil.

Studies are under way dealing with the isolation and characterization of the proteins of the corn kernel and the proteins of gluton by products of the milling operation, and of fermentation residues, with the objective of developing now and improved industrial uses for these materials. An important development to date is the preparation of excellent films from the corn protein "Zein" which have the desired properties for uses in industry as paper sizes, etc.

V. THE WESTERN LABORATORY

It was not intended that research on foods, should be carried on in the Regional Research Laboratories, but that they should be concerned solely with the utilization of farm products for industrial purposes. However, the urgency of many problems connected with the production, processing and preservation of foods in wartime has made it necessary to turn over a considerable part of the research facilities and staff of the Western Laboratory to researches in this field. Of those investigations, reference will be made only to those which, in the writer's opinion, may affect the future of the food industries.

Research in Progress: (i) Utilization of Minor Oil-Producing Crops.

Reference will be made only to byproducts of interest to Canada. With the rapid growth of the fruit canning industry in Canada, attention has been drawn to waste products, such as pits, and the possibility of utilizing them in profitable ways. Unfortunately no information is available as to potential supplies residing in the wastes from processing plants. In normal times, the project has not been considered practical because of economic factors such as decentralization, or lack of sufficient material in the smaller plants to justify either recovery equipment or haulage to an oil-pressing plant.

In view of present disturbed economic conditions, it is well to consider more carefully our resources of certain crops and commodities that are of minor or auxiliary character such as the lesser known and little used vegetable oils, which may be byproducts of crops grown in considerable abundance. It is a fact that oil prices in general have risen sharply in the last year due to our own increased needs, and lowered imports. The situation is, of course, an unusual and artificial one but it is also true that decisive and permanent changes in trade and commerce will result from the present state of flux. Domestic producers will receive benefit by absorbing markets which in times past have gone to foreign competitors. Byproduct industries will receive the impetus which previously was denied and profits will accrue from former waste materials.

Processing residues of fruits and vegetables and unmarketable grades of such commodities are the first materials to which it is logical to turn in search of vegetable oils, for at least a part of such wastes embraces seeds which are oil-bearing. Pits from the dried fruit industries, and tomato, apple and grape waste from canneries and byproduct plants are rich sources of easily obtained and readily refined edible oils.

Fruit Pit Oils

The pit oils of the apricot, peach, and cherry bear a striking resemblance to each other in composition and indeed are with difficulty distinguishable one from the other. They are like sweet almond oil for which they are often substituted as specialty oils handled by essential oil brokers.

Apricot Pits: Four plants in California buy and shell apricot pits in amounts as high as 14,000 tons per year if the crop is good. Apricot kernels are in demand as a substitute for almonds in bakery goods, though it is necessary to process them first in a way that will remove the bitter taste and liberate the hydrogen cyanide, such as by heating the ground meats in a current of steam. The bulk of this product formerly was exported to Europe but the domestic market is now the only one available. There is no market for broken meats that result incidentally from the shelling operation, and to minimize the loss that would otherwise be sustained these are pressed for oil, which is sold to the cosmetic and drug trades at the now very good price of 40 to 48 cents a pound. The present market, however, is a distinctly limited one, probably not in excess of 150 tons. The 14,000 tons of pits previously mentioned would yield, if all were pressed for oil, about a thousand tons in round figures.

At present there are two companies in California engaged in pressing pit oils, of which apricot is the chief. The cracking, separation of shell from meat, and pressing present no difficulties. If the meats are floated from the shell in brine, they must be promptly washed and dried to prevent hydrolysis of amygdalin and consequent release of "oil of bitter almonds" into the fixed oil. Refining losses can be held to a low figure. The oil

bleaches easily and is sufficiently bland that no deodorization is required. It is an excellent cooking and salad oil. The meal is nitrogenous and is sold for lawn fertilizer.

Peach Pits: A few tons of peach-kernel oil are being pressed by one or two small plants in California. Like the closely related apricot oil it can be refined and bleached to a sparkling light-colored bland oil ideal for a general cooking and salad oil. It is in small demand by the cosmetic trade.

The peach kernel represents only about eight percent by weight of the pit whereas apricot kernels run close to 25 percent. In considering utilization of both kinds of kernels, a profitable return on the shells is highly desirable. No particularly exclusive uses are known for the shells. Some shells have been ground for use as dynamite base, carbonized to make absorbent chars, and blended with carburizing compounds; some have been applied in the coarse form as a loose surfacing material for drives and parking areas. Whole peach pits are ground and briquetted for fuel by one western plant.

It might prove profitable to remove the volatile oil of bitter almonds from the meal by steam distillation. Finely ground, light coloured meal has been used in beauty packs for its rubefacient properties.

Cherry Pits: The excellent qualities of cherry kernel oil for the exacting requirements of the pharmaceutical and cosmetic trades are well known. Cherry pits represent 12 to 15 percent by weight of the fruit and contain about 11.2 percent of oil. If all the pits from the cherries canned in Californian factories were made available for oil, about 600 tons of oil could be obtained.

The oil has a somewhat higher iodine value than apricot and peach pit oils but not sufficiently high to place it in the drying class. It has good keeping qualities. The meal contains 30 percent or more of proteins and an amygdalin similar to that present in peach and apricot meals. One company in Wisconsin is known to have produced cherry-pit oil in amounts less than 50 tons, per year but is no longer operating. In quite recent years, another middle western company has produced natural cherry flavor by steam distillation of the ground meats but did not recover the fixed oil.

Seed Oils

Oil-bearing seeds from various agricultural products are numerous. Large quantities of apples, grapes and tomatoes are processed in centralized plants where the seeds form a considerable portion of the waste products and are separable with little difficulty. Edible oils may be expressed from them by conventional methods and provide an additional source of income from the parent crop, although returns to individual growers whose interests are pooled in large concerns would not be much in most cases.

Tomato Seeds: On the average the seeds contain 20.5 percent of oil and represent 0.55 percent of the whole tomato. The press cake from tomato seed is quite rich in protein and would be a valuable stock feed.

In years past the U.S. Department of Agriculture has investigated tomato seed as a source of fixed oils and the general problem of the utilization of tomato waste. These studies included the important factors incidental to the subject, such as handling and sorting tomato waste, cleaning of the seed, extraction and refining of oil, cost analysis and possible returns. At the time of this investigation only 400 tons of tomato seed oil were potentially available; since then the available quantity has risen to 2,170 tons, and the general economic picture has changed. There is no production of tomato seed oil in the United States at the present time. One solvent extraction plant was put in operation in Los Angeles a few years ago but was not successful, perhaps because of faulty design.

Freshly expressed tomato-seed oil is brownish to reddish in color and has a strong odor. When the crude oil is refined by caustic soda, bleached and deodorized, a pale yellow product is obtained which is entirely suitable for culinary purposes. In Italy the crude oil is chiefly used in soap making.

The tomato processing industry is widespread. Canneries are located in all parts of the country. Disposal of tomato waste is frequently a problem

to canners when it becomes a nuisance as in stream pollution. This is solved in isolated instances by drying the whole waste in rotary kilns and selling the ground product for stock feed. Separation of the seed and recovery of the oil would enhance profits from this material provided plant capacity were sufficiently great to warrant installation of equipment.

Grape Seeds: In California the seeds from one processing plant alone justify the operation of a byproducts plant which recovers high-proof spirits by fermentation of the adhering pulp, presses oil from the seeds, and combines the meal with ground raisin stems for stock feed. The extensive wine interests in California are quite conscious of the desirability of using their pomaces for recovery of grape-seed oil. The chief difficulty here is the lack of centralization of the industry. The report of one company indicates that it annually processes about 35,000 tons of grapes, of which about 70 percent are seed bearing varieties. It is estimated that the grapes used by this one company would yield by extraction methods about 90 tons of seed oil per year. In tests made by the company, seeds were removed to the extent of about 85 percent by discharging the twice-washed pomace upon rotating screens and drying to about 12 percent moisture content. Seeds are high in silica and therefore hard on grinding equipment, expeller barrels and pressing clothes. It was concluded that grinding to about 40-mesh and solvent extraction would be the proper means of oil recovery.

The tonnage of wine grapes in California is about 776,000 tons of which approximately 543,200 tons are seed bearing varieties, the seed equivalent being 16,296 tons. Estimated at 12 percent the total recoverable oil is, therefore, about 2,000 tons.

Apple Seeds: The cull fruit, which may average 120,000 tons annually, is a potential source of byproducts. The problem of what to do with the culls, however, is still far from solution and therefore only that part of the crop which is actually processed need be considered in estimating the oil that could be obtained from apple seeds. Apple products industries in the United States use about 744,000 tons of fruit annually. If it is assumed that the dry weight of the seeds amounts to 0.25 percent of the weight of the fresh fruit and that they contain 25 percent of oil, 744,000 tons of apples would represent 465 tons of oil.

It is obvious that except for certain regions, where apple production is concentrated in small areas, recovery and collection of the seeds would be especially difficult. Hence, until the larger problem of cull utilization is solved, apple seeds can hardly be regarded as a likely source of oil.

Vegetable Seeds: Oil-bearing seeds from squash and pumpkin are present in the waste material from factory-canning of these vegetables. The seeds contain about 30 to 35 percent of oil, which has an iodine value of 120-130. In Central and Southern Europe, pumpkin seed oil is used for edible purposes. No oil recovery from these seeds on a large scale has ever been attempted in this country.

(ii) Pectins

Pectins are the substances or mixture of substances extracted from fruits by suitable means which in association with sugar and acid or the acid juices of fruits, form jellies. Ideal raw materials for the manufacture of commercial pectin extracts and anhydrous pectin are apple pumace (15-18% pectin dry basis) and beet pulp, a byproduct in the manufacture of beet sugar. (25-30% pectin dry basis).

The waste available from most apple processing plants is not ideal raw material for the production of pectin because fully ripe fruit is treated, and this is not what the pectin industry wants. A large tonnage of apple "thinnings" is potentially available and these green apples would be excellent raw material. These apples are thinned from the trees to leave more space for the residual fruit. It is understood that they are collected for reasons of pest control and then discarded.

Two outstanding physical properties, gel formation and adhesion, are responsible for the great commercial importance of pectin. Wide use of this material has been made in the manufacture of jellies, jams, and marmalades;

as a stabilizer for tomato juice and catsup; as an emulsifying agent in the baking and confection industries; and in salad dressings. Pharmaceutically it is used in the manufacture of emulsions of castor-oil and mineral-oil laxatives. Further it is employed as a powder alone or mixed with kaolin for the treatment of dysentery, this use being based on the discovery that pectin inhibits the growth of many intestinal pathogens. Many other uses are being evaluated such as in the preparation of tree-spray emulsions, the manufacture of mucilage, and as a blood agglutinant in the dressing of wounds.

The demand for pectin has increased enormously in recent years. Two million pounds were used in 1938 and 4 million pounds in 1942. The Citrus Concentrates Inc., Dunedin, Florida, is building a plant which will begin production next year at the rate of 800,000 pounds per annum. A plant was built in 1940 at McAllen, Texas by the Sardic Corporation Inc., to produce 250,000 pounds per annum of nickel pectinate from grapefruit rind procured from the canneries. Six million pounds of pectin are said to be required for lend-lease. The price of 100 - grade pectin is $1.00 per pound.

To afford a firm foundation for the further industrialization of pectin, a broad program of research is underway in the Commodity Byproduct Division, Studies are being conducted on the constitution and physico-chemical properties of pectin but these will not be discussed here; some of the more applied work is referred to below.

(a) The use of pectin materials to replace imported vegetable gums.

Gum-arabic, agar-agar and tragacanth, imported gums, are used for sizing and dressing in the textile industry; as emulsifiers; as binding agents in the paint and adhesives industry and for various purposes in the food industries. The available supply is now inadequate for war and essential civilian use. Pectin is being study as a substitute emulsifying agent in high quality oil emulsion etc. It may be used in vegetable (salad) oils and in mineral oils and is superior to tragacanth and readily replaces acacia, but the viscosity is high. The cost of pectin for use as an emulsifying agent is favorable, even in normal times.

(b) Pectin as an emulsifier in pharaceutical ointments.

They have developed several types of washable tannic acid ointments with pectin as a base and containing the sulfadrugs. These ointments have been prepared according to Navy Department specification. Notwithstanding the fact that pectin of high purity must be used the economics is very favorable.

(c) Production of Pectin derivatives.

Pectins of varying degrees of methylation have been prepared which form gels with varying concentrations of sugar or acid. A preparation has been obtained which will gel with or with sugar. It is a mixed metallic salt of partially demethoxylated pectin (i.e. pectinic acid and partially demethoxylated pectin plus calcium chloride). The importance of an available supply of this material at the present time is evident. It will jelly with 30% sugar and may be actually advantageous from the standpoint of taste. As a substitute for gelatin it has certain advantages as it gives a clear thermostable gel. The material is best prepared from 300-grade apple pectin in which the degree of polymerization is high enough so that when demethoxylated there is still enough polymerization. Efforts are being made to utilize ordinary cheaper grades of pectin.

(d) Use of pectin in the freezing-preservation of fruits.

The fruit is treated with a special pectinate which forms a protective coating and prevents "bleeding" when the fruit thaws. It is particularly successful with strawberries. The preparation of a thiourea derivative of pectin is being attempted which may simultaneously prevent "bleeding" and blackening of the fruit due to oxidation.

(e) Pectin as a substitute for agar in bacterial cultures.

This investigation was undertaken because of the serious deficiency in the agar supply. So far it has not been very successful as the

material wont stand up in the ordinary sterilization process. Intermittent sterilization at 100°C is satisfactory and they have cultured and plated out a few organisms using pectin media. They are hopeful that a more thermostable material can be developed.

(f) Preparation and studies of d, galacturonic acid from Pectin.

A method has been developed for the quantative preparation of d, galacturonic acid from apple pectin by the action of a pectinase enzyme, "Pectinol 100 D". The acid can be prepared free from contamination with heavy metals and in quantity at nominal cost. New uses are being sought for galacturonic acid as a bactericidal and detoxifying agent. The methlyester of galacturonic acid is believed to be the active therapeutic agent in apples.

(iii) Utilization of Vegetable Oils.

Laboratory and pilot-plant studies are being carried out on the various processes for separating the oil from oil-bearing seeds, including hot-pressing and solvent extraction methods. A search is also being made for new industrial uses for saturated fatty acids*. These studies include the utilization of saturated fatty acids as plasticizers and their modification to give more soluble soaps, with improved detergent properties to compare with lauric or oleic soaps. Fatty acid esters of Xylitol (from wheat hemicelluloses) including the penta-palmitic, stearic, and lauric esters, have been prepared and their plasticizing properties are being studied. The object is to find plasticizers for resins to replace phthalates which are becoming increasingly difficult to obtain due to the war.

The solvent extraction of vegetable oils is discussed in more detail below:

Solvent Extraction of Vegetable Oils:

Two types of pressing methods are employed commercially for expressing the oil, viz., (a) the hydraulic plate press, and (b) the expeller process. In recent years, more consideration is being given to extracting the oil by solvents. The advantage of solvent extraction is that a greater recovery of oil is obtained; the residual meal contains one percent or less of oil, whereas the residual meal from the presses contains 5-8% oil. This increased yield of oil is important to industry, particularly at the present time, and the fact that the meal contains less oil and has been processed at a lower temperature is also important if the meal is to be used as a source of protein for plastics. On the other hand, the higher oil content of pressed cake is advantageous in livestock feeding as it improves the physical consistency.

Among the principal reasons for continued adherence of pressing and expelling methods, which leave a substantial residue of oil in the meal, three are predominant; (1) an adequate technical background for some phases of solvent processing is still lacking; (2) a large initial investment of $500,000 to $1,000,000 per plant would be required; and (3) the availability of pressing equipment capable of handling the entire crop without difficulty is a deterrent to further investment in plant facilities.

For economically sound operation, a solvent extraction plant should have a capacity of several hundred tons daily and should be worked the year round. Wartime shortages of metals and other supplies would make difficult the immediate adoption of any such new method by the industry, even though additional supplies of vegetable oils may be needed. Nevertheless, solvent extraction methods are scientifically and technologically sound and hence deserve searching consideration.

Only a few of the growing number of commercially available organic solvents meet the requirements for edible oil extraction. A suitable solvent should be highly purified, easily evaporated, and unreactive. Preferably, it should also be non-toxic, non-flammable, and inexpensive. No solvent meets ideally all these specifications; the only one used in considerable quantities is a low-boiling, highly refined fraction from petroleum (petroleum ether, hexane). Many other organix solvents are somewhat better oil solvents, but they also extract more gums, coloring matter, and other extraneous substances, and they are all much higher in cost.

* Similar investigations on the unsaturated fatty acids, being carried on in the Eastern Laboratory, have already been discussed.

Chlorinated hydrocarbons, such as di-or tri-chlorethylene, are reported to have been used successfully in Europe for oil extraction. They have the advantages of non-flammability and of greater solvent action than petroleum ether. Doubt has been expressed concerning the feasibility of using them on a large scale in metal equipment, because of the possibility that hydrolysis would result in the evolution of hydrochloric acid which would cause serious corrosion. Nevertheless, their satisfactory application abroad indicates that such engineering problems can be surmounted.

The E.I. du Pont de Nemours Co., Wilmington, Delaware, has done considerable development work on their own product, trichlorethylene, as a solvent for extracting vegetable oils. Its advantage lies in the fact that it is a stable, efficient, and non-inflammable solvent; its disadvantage is its cost - $1.00 per gallon as compared to hexane costing 12 cents per gallon. It is claimed that trichlorethylene is the best solvent for use in small-unit extractors, no fire protection equipment is necessary and it can be recovered in high yield and used over and over again, and the capital cost of the plant is greatly reduced.

A small-scale oil extraction plant, suitable for the use of the solvent, has been developed by the Detroit Rex Products Co., Detroit, Michigan, which is of unusual design. By means of a conveyor screw the meal is moved forward against a counter-flow of the solvent. The extracted meal is raised from the pool of solvent, deposited in a horizontal drying tube and leaves the machine in a toasted, solvent-free condition and makes a very palatable cattle food. The oil is stripped of its solvent and leaves the still as a crude oil also entirely free from solvent. The "Detrex extractor" has processed 15,000 bushels of soybeans in 9 months of operation.

Instead of transporting oil-seeds long distances to large extraction plants, located in cities, and shipping the byproduct meal back to the farm it might be more logical to process the seeds in the area where they are grown and where the byproduct feed is consumed, and ship the oil to centralized refining plants. A small-scale extraction unit using a stabilized non-inflammable solvent, such as that described above might be suitable for the establishment of rural industries of this type.

(iv) Production of Plastics from Agricultural Materials

The growth of the plastics industry during the past ten years has been amazing; plants are being erected today to produce many millions of pounds of synthetic resins of the phenol-formaldehyde, urea-formaldehyde, vinyl, and glycerolphthalic anhydride types. Since the beginning of the war, with the accompanying shortage in certain metals, more and more attention has been focused upon the replacement of metals by plastics for a great variety of uses.

Much has been said on the utilization of plastics as building material and consideration is being given to the prospect of utilizing the wartime output of the plastics industry for post-war reconstruction, when the demand for building materials is likely to be heavy. Technical information must be available in advance so that plastics may be used to the best advantage. Any structural use must conform with requirements similar to those governing the use of structural steel and timber. A reasonable degree of durability is required and costs must not be unduly high. Plastics have already an established reputation for use as decorative wall coverings, as fittings, and for sundry other building purposes. Improvements will need to be effected in certain of their physical properties if they are to be used in competition with wood and steel as load-bearing parts of buildings.

Synthetic plastics are relatively expensive and if plastics are to be used in the building industry it would demand a low-cost plastic material which can be made from some abundant raw material. Products from the soybean are being exploited. Furfural and lignin resins from waste-agricultural products and sulphite liquor may eventually provide relatively cheap supplies for the manufacture of constructional materials.

The Iowa Engineering Experiment Station, Ames, Iowa, has recently announced the production of plastics of high impact strength and low water absorption from low-cost agricultural products and byproducts.

A dark brown resin is produced by heating together extracted soybean meal, furfural, phenol, and ammonium hydroxide. This resin, when mixed with

hexamethylenetetramine and either wood flour or asbestos filler can be molded into plastic products which compared favorably in strength and water absorption with samples molded from commercial phenolic molding powders. Variations in relative proportions of ingredients, in methods of procedure, and in time and temperature of cooking have been studied in relation to the strength and water absorption of the finished product. Urea can be substituted for phenol, producing a substance of satisfactory strenght but higher water absorption. Soybean meal can also be hardened by furfural alone and molded into a product of good strength but high absorption.

A plastic molding material can be made by heating together corncobs (or oat hulls), cresol, and sulfuric acid. This product can be molded directly without the addition of fillers. Another product, made in the same general manner except that it contained a much larger proportion of cresol, can be mixed with filler to give a thermoplastic molding powder. When furfural, hexamethylenetetramine, and filler are added to the thermoplastic material a thermosetting product is produced. Samples molded from these materials, although somewhat less in strength, are lower in water absorption than the soybean plastics. The optimum proportions of ingredients and the optimum cooking conditions have been established.

Acid-hydrolyzed cornstalks and oat hulls when mixed with furfural, aniline, filler, and in some cases other materials, can be molded. The effect of varying the raw material combinations and molding conditions has been studied. Plastics of desirable strength but rather high water absorption are produced. Raw material costs for all of these products are low.

The protein division of the Western Regional Laboratory has undertaken the study of the manufacture of plastics, for specialty purposes, from animal byproducts such as feathers, hoof-meal and hog-hair. The estimated supply available at centralized packing plants is not very large, amounting to about 50 million pounds of feathers, 10 million pounds of hoof-meal and 25 million pounds of hog-hair. However, the situation is constantly changing and the economic utilization of these materials will finally depend upon the success achieved in manufacturing plastics therefrom which can compete with the high priced synthetics. The following summary will indicate the progress they have made:-

(1) A rapid, efficient, and inexpensive method has been developed for extracting the "keratin" protein from hoof, hair and feather, to be used for plastics. The finely ground material is dispersed in sodium sulfide solution, auto claved, filtered, and the protein precipitated with acetic acid.

(2) Plastics of high impact strength and almost metallic fracture have been made with equal parts of keratin-protein, redwood fibre; and urea-formaldehyde resin; the protein being used as an extender for the resin. Numerous articles have been pressure molded using this mixture. Urea-furfural was unsatisfactory.

(3) Modification of the protein is being attempted so that it will flow more freely and so that it can be ejected from the hot die (thermosetting)

(4) The most promising uses for the keratin-protein are in the preparation of improved water resistant glues; as an extender with casein glue in plywood and as a protein extender for resin-bonded plywood. The keratin-protein mixed with dried (fertilizer) blood makes a good plywood glue which sets faster than animal glue alone.

(5) The formation of fibres from non-fibrous native proteins is also being studied. With the use of detergents it has been found possible to control the transformation so that the precipitated protein could be drawn into fibers. The reaction of protein molecules with synthetic detergents is being studied.

(v) Utilization of Wheat and Milling Byproducts

Research on wheat as an industrial raw material is being carried on in the Western Laboratory. Special attention is being given to the utilization of gluten, germ-oil, and hemicelluloses; wheat starch is being investigated in the Northern Laboratory. The successful industrial utilization of wheat will depend upon the development of a coordinated industry making full use of the germ, gluten, starch and structural carbohydrates. Research on the development

of more efficient and cheaper commercial methods of separating these fractions will be required. This is essentially a chemical engineering problem necessitating work on a "pilot-plant" scale.

Wheat Starch:- The 1939 Biennial Census of Manufacturers reports production of wheat starch at between 10 million and 16 million pounds. However, it is thought that rice and miscellaneous starches are included in this figure. The chief difficulty in the manufacture of wheat starch lies in the inability to dispose of the starch and starch byproducts, due to the high cost of wheat starch compared with other starches. The Huron Milling Company has been trying for over 40 years to develop the wheat starch business. They say that any great increase in the sale of wheat starch would be difficult to accomplish, and they obviously cannot produce the gluten unless they can sell the starch. Production of first quality starch from wheat is about 50%. Using the top Census figure for manufacture of wheat starch, there is needed 32,000,000 pounds of flour to make 16,000,000 pounds of starch (50% of flour) and 4,480,000 pounds of gluten could be obtained in the manufacture of this amount of starch (14% of flour).

Fields of use for wheat starch are limited because corn starch is not only cheaper but is also superior for most uses. Wheat starch can replace tapioca in some instances but there again is the question of price. Low grades of tapioca sell far below wheat starch.

Wheat Gluten:- There are only two firms of any size in the United States which make wheat gluten - The Huron Milling Company and the Keever Starch Company. One company makes gum-gluten and devitalized-gluten, both having the same protein content, with a guaranteed 80% protein or better, on a moisture-free basis. Gum-gluten is made so that it retains all its natural gumming properties whereas devitalized-gluten has no gumming properties. About 10% of production is gum-gluten and 90% is in the devitalized form. Quantity and quality of wheat gluten depend upon the kinds of flour used, some yielding as low as 10% and others as high as 15%.

Gum-gluten is sold chiefly to flour mixers for use in making gluten breads. The larger part of the devitalized-gluten is used in the manufacture of mono-sodium glutamate; the remainder is used in making bouillon cubes and similar products; tyrosin, crystine, leucine and hydrolized protein for food seasonings.

The Keever Starch Company produces about 50,000 pounds of wheat gluten per month of which 10,000 pounds is vacuum-dried gluten, used in the manufacture of special foods for diabetics. The remainder is sold to makers of various kinds of sodium glutamate flavors and related products.

Some of the investigations on wheat-gluten being carried on by the Protein Division are reviewed below:

(1) The Separation and drying of gluten:

The mechanical separation of gluten from wheat flour is being studied in pilot-plant operations. The drying of the sticky mass of gluten is best achieved by freezing and vacuum-drying, using a dessicant which can be regenerated.

(2) The gluten plastics which have been prepared have a pronounced tendency to absorb water. Plastics have been made from gluten - cellulose - phenol formaldehyde mixtures in which the water absorption is reduced from 5% to less than 0.5%. Formaldehyde or ketone don't reduce the water absorption of gluten very much and in this respect gluten differs from soybean protein. Fibers have been made from this plastic. Silky, glistening fibres have been obtained with a decided advantage in color over vegetable proteins but with the usual inherent disadvantage of being too brittle. The economic use of gluten in plastics will depend upon finding that it possesses unique properties analogous to its properties in bread making. So far, no such properties have been discovered. The preparation of gluten films for papersizing, similar to those produced from "Zein" in the Northern Laboratory, is being attempted.

(3) Use of gluten in detergents.

A complex of an aryl sulfonate and gluten makes a fine detergent with good lathering properties. However, a better product can be made from casein since part of the gluten detergent is insoluble in water. Gluten-sodium sulfonate is a light fluffy material which absorbs an enormous quantity of water and sets to a irreversible gel. This material has been tested in a San Francisco hospital for the absorption of drainage from wounds. It has proved very satisfactory and is believed to promote actual healing. This phase of the work is being reported in the Journal of the Americal Medical Society.

(4) Fractionation of gluten.

The gliadin fraction of gluten has been found to have excellent adhesive properties and could probably command a higher price for special uses. Enquiries regarding gliadin adhesives have been received from the Lockheed Aircraft Corporation.

(vi) Production of Pharmaceuticals from Agricultural Materials

The Biochemical Division of the Western Laboratory was established to serve all of the regional laboratories by pursuing any promising lines of investigation of pharmaceutical interest arising out of discoveries made in these laboratories. Particular attention is being devoted to the production of antibacterial agents of microbial origin, as a war project. Chemical substances are produced by certain molds which are antagonistic to bacteria and one of these is "Pencillin" extracted from a specially selected species of mold, grown on corn sugar. It inhibits the growth of pathogenic organisms: exhibiting properties which would enable it to replace iodine and supplement the sulfadrugs. The commercial production of "Pencillin" is being studied in the Northern Laboratory, already with considerable success, yields having been increased twenty-fold. Its production, in sufficient quantity to meet the needs of surgery alone, would require quite considerable amounts of corn sugar for media.

Another chemical substance "Gramicidin" produced by Bacillus brevis, inhibits the growth of pathogenic, gram-positive bacteria. The commercial production of "Gramicidin" is being studied in the Western Laboratory also with considerable success. Asparagus juice has been found to be an excellent medium in which to grow the organism and gives an increased yield of "gramicidin". Large volumes of asparagus juice would be required for large scale commercial production so efforts are being made to prepare a concentrate of the juice containing 40-50% solids from which has been removed any material which might interfere in the isolation of "gramicidin". Spray-dried asparagus juice was found to be unsatisfactory, probably because of the decomposition of some constituent essential for the growth of the organism.

Other problems being investigated in this division are: (a) domestic sources of proteases to replace "papaya" imported from Hawaii and used to tenderize meat; (b) production of "lysozyme" from egg white to be used as a food preservative; (c) preparation of antiseptic ointments using agricultural products including pectin, tannic acid, gramicidin and vegetable proteins as sources of sulfhydryl compounds and (d) production of B vitamins by growing yeast on waste-fruit residues.

(vii) Dehydration of Foods

The dehydration of foods has always been a primary interest of the food processing industry because of the advantages in weight and bulk, and hence economy in storage and transportation, which the dehydrated product possesses. In normal times, however, the industry has not prospered, primarily because of the poor quality and high price of the product. In World War 1, a considerable volume of dehydrated food was produced and consumed through dire necessity. About nine million pounds of dehydrated vegetables were used by the American army and large amounts were produced in other countries. Following the war, several companies continued drying vegetables but without much success in civilian sales; and soon gave it up. Some continued to operate, with moderate success, particularly in specialty foods such as vegetable soup mixture; pumpkin flour for use in pies, jerusalem artichoke flour for use by

diabetics; and onion flakes, onion powder, and garlic powder for use in flavoring.

When dehydration for the army and navy was resumed in this war an extensive program of research was undertaken in this country and in the United States with the object of improving the palatability and nutritive value of the products. Furthermore, the tin shortage curtailed the canned food pack and commercial packers were compelled to consider dehydrated foods for civilian use. Research on dehydration (vegetables, meat, and eggs) has met with such spectacular success that there would appear to be no doubt that this will be an important industry for some time to come. The United States will produce 25 million pounds of dehydrated vegetables this year and a coordinated program for the expansion of dehydration facilities is in operation to increase production to 90 million pounds in 1943.

The future of the industry after the war is problematical but some leaders in the industry no longer look upon it as a temporary or stop-gap operation but as a permanent industry. With careful handling, one can supply the consuming public with a product richer in vitamins than may be obtained from the local grocer - leafy vegetables, for example, lose a large part of their Vitamin C content merely by standing overnight. Many vegetables can be dehydrated so that the cooked product is indistinguishable from the cooked fresh vegetable.

Precooked, dehydrated potato may find a large permanent market after the war because of the economy in transportation; elimination of waste; and convenience in domestic cooking. The combination of potato drying with starch manufacture might reduce the costs of producing both commodities since potatoes could be purchased "field run"; those unsuitable for dehydration could be diverted to starch manufacture and starch could be recovered from the parings from the dehydration unit.

The Western Laboratory is studying many problems connected with the dehydration of vegetables as part of a larger organized research program of the Dehydration Committee of the Bureau of Agricultural Chemistry and Engineering. The following short review will indicate the nature and scope of these investigations.

(1) Survey of Vegetable Production:

This survey has been completed and will form the basis for an intelligent appraisal of proposed locations for dehydration plants and their size. In order to get low costs of production, expended acreage for dehydration should be (a) in areas of suitable soil type and climatically adapted to the crop, (b) with growers acquainted with its production, (c) where land values are not excessive and (d) where equipment and labor is available for large scale production. Other factors besides the potential supply of raw material must be taken into account, for example, the surplus requirements over fresh-market needs by densely populated areas.

(2) Preparation and Blanching of Vegetables for Dehydration:

Successful preservation begins with the quality of the raw material because quality will not be improved by drying. On the basis of present information it would seem to be desirable to blanch all vegetables. One of the results of blanching is the inactivation of most of the enzymes that are believed to cause undesirable flavour, color, and texture, and vitamin loss in dehydrated vegetables.

Two methods of blanching or scalding, with steam or water, are being studies. Tests for detecting the enzymes (catalase and peroxidase) in improperly blanched vegetables are specially important. Simple tests are being devised for use in dehydration plants by relatively unskilled operators.

(3) Basic Engineering Principles of Dehydration:

A fundamental approach to the mechanism of dehydration is being made through studies on the theoretical aspects of dehydration and types of dehydraters. Three designs are being considered: counter-flow, parallel-flow, center-exhaust. In the counter-flow tunnel, with wet material entering the exhaust end, the drying rate is slow at the start, rapid in

the center and slow again at the end as the product becomes dry. The parallel-flow has a rapid drying rate at the beginning, but the dry product and the moisture-laden cooler air leave at the same end, so that unless the air velocity is very high, the product is never so dry as in the countercurrent. The center-exhaust type is an attempt to combine the initially high drying rate with a final low moisture content. This type, while unfamiliar in the United States has been used very successfully in Canada.

Consideration is also being given to designing dehydraters to operate on an entirely new and revolutionary principle, that is, drying the product in an atmosphere of super-heated water-vapor in a closed system.

(4) Storage and Packaging Problems:

Extensive storage experiments at temperature of 85-90°F, are underway to determine the effect of blanching procedures and the moisture content of the product, on palatability, color and vitamin value. The moisture content has the most important influence in storage. Microbial growth is prevented at low moisture contents, and color and vitamin retention are all improved. As an illustration, the rate of loss of vitamin C is from 4 to 8 times greater with cabbage at 8% moisture as compared with similar cabbage at 4%. There is no evidence that benefits resulting from a reduction in moisture cease at the commonly specified moisture contents. The desirability of further reductions must be balanced against added costs. It has been concluded that for year-long storage, the moisture pick-up should not exceed, in general, 2% of the original dry weight of the package.

The ideal package should be impermeable to water vapor, gases and light, and also should keep out insects. It must have a lining of adequate strength, if backed up by a carton or box in shipment. Before the war, tin plate containers were used in all but the smallest sizes and these were ideal. Aluminium foil, laminated with rubber hydrochloride has been widely used for dried soup mixes.

Substitute packages include cellophane linings laminated to sulfite paper; glassine, moisture-proofed and laminated in the form of a double bag; unbleached super-calendared sulfite paper waxed with 8 pounds of wax (m.p. 135°F.) per ream; parchment, double waxed. In the foregoing, the transmission of water vapor is calculated to be under the desired 2% per year. The weight of water absorbed through any particular package is proportional to the surface area of the package lining, to the water vapor pressure difference inside and outside, and to the time.

(5) Cost of Production:

Cost is likely to be the greatest obstacle to the successful introduction of dehydrated vegetables on the post-war domestic market. A summary of costs estimated by the Western Laboratory follows:

	Cost per dry pound	Drying Ratio	Labor cost per dry pound**	Equivalent cost per fresh ton
Potatoes	36¢*	7	9¢	$108
Carrots	52	9	11	115
Beets	52	9	13	115
Onions	85	13	12	131
Cabbage	52	18	15	53
Turnips	52	9	10	115

* Burden 7¢, labor 9¢ and raw material 20¢.
** Labor - men 75¢ per hour; women 60¢ per hour.

They are working on a small farm dehydrater of about four-ton capacity. This is "small" in comparison to commercial dehydrators, and is intended not to dry foods for home use but to enable the farmer to dry his own crop. One difficulty is that the cost of a dehydrater is not proportional to the size. As the size is reduced the cost per ton capacity is increased. They believe that four-tons is a good balance between cost and usable capacity for the average farmer.

Other problems engaging the attention of the Western Laboratory are:-

The spray drying of eggs is being studied with particular reference to the production of a stabilized product. Vanillin shows promise as an anti-oxidant. Dehydration of eggs in the frozen state is being tried. Storage studies similar to those with dehydrated vegetables are also underway.

The storage of alfalfa in inert-gas atmospheres to preserve its carotene content: the recovery of carotene and of proteins or protein concentrates from alfalfa; the conversion of alfalfa protein into useful fibers, films, adhesives or plastics.

The frozen-packing of apples, fruits, vegetables, or poultry products; portable blanching and freezing units; improved methods for handling, packaging, and storing frozen foods; the economical farm preparation of fruits or vegetables in conjunction with mobile freezing units or commercial locker plants; controls for relative humidity in refrigerated storage spaces; mathematical analysis of the flow of heat during the cooling and freezing of apple slices, fruits, poultry, and vegetables to provide rational basis for design of freezers.